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PITCH RATE FLIGHT CONTROL SYSTEMS IN THE FLARED LANDING TASK AND DESIGN CRITERIA DEVELOPMENT

C.J. Berthe, C.R. Chalk and S. Sarrafian

Calspan Final Report No. 7205-6

TECHNICAL REPORT

ARVIN CALSPAN ADVANCED TECHNOLOGY CENTER P.O. BOX 400 BUFFALO, NEW YORK 14225

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16. Abstract

An in-flight investigation of the performance of pitch rate command flight control systems in the flared landing task was conducted at Buffalo, New York during September 1983. A shortcoming of these types of flight control systems is the tendency to float during flared landings. This floating tendency results in flying qualities ratings that can't be consistently predicted by classical predictive criteria. In this program some twenty seven flight control configurations were tested in flight. The configurations included conventional and superaugmented pitch rate command systems, neutral static stability cases, shuttle like configurations, a conventional Level 1 aircraft, and configurations that included pre-filters to improve flying qualities of pitch rate command systems. The results of the flight program demonstrated improvements from Level 2 and 3 to Level 1 performance by the use of the pre-filters. A lead/lag filter provided more rapid initial responses for better flight path control and a washout pre-filter provided monotonic pitch control forces during the flare which are lacking in rate command systems. Various classical frequency domain predictive criteria were applied in the analysis, and a method using the bandwidth criteria closed on altitude-rate (vs attitude) shows promise. In addition, a Time Domain predictive criteria was developed that appears to improve flying qualities prediction for the flared landing task.

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FOREWORD

This report was prepared for the National Aeronautics and Space Administration, Ames Research Center, Hugh L. Dryden Flight Research Facility, Edwards, California and Langley Research Center, Hampton, Virginia by Arvin/Calspan Advanced Technology Center, Buffalo, New York. It covers the preparation, conduct, and analysis of an inflight simulation program investigating pitch rate command flight control systems in the final approach and flared landing task. The aircraft used was the USAF/AFWAL Total In-Flight Simulator (TIFS) which is operated by Calspan under Air Force Contract No. F33615-79-C-3618 and F33615-83-C-3603. The program was sponsored by NASA and administered by USAF/AFWAL.

Mr. Donald Berry was the project manager for NASA/Ames/DFRF, Mr. William Grantham for NASA/LRC and Capt. Michael Maroney was the program manager for AFWAL.

The work reported here was performed by the Flight Research Department of Calspan. Dr. Philip Reynolds was the TIFS program manager, Mr. Charles Berthe was the project engineer, calibration pilot, primary safety pilot, conducted the analysis and was the author of this report. Mr. Charles Chalk developed the flight control system improvements used in this program and was overall program advisor and co-author of the report. Mr. Shahan Sarrafian of NASA Dryden was the flight test engineer and also co-authored this report. The evaluation pilots were from NASA/LRC and NASA/DFRF.

The author wishes to acknowledge the contributions of individuals who contributed to this program. Mr. Charles Chalk a co-author who's tutoring and technical assistance made this report possible, Messrs. Robert Harper, Michael Parrag, and John Ball safety pilots, Messrs. Robert Gavin, Ralph Siracuse and James Lyons, computer and electronic systems preparation, Mr. James Dittenhauser, who makes TIFS work, and Ms. Chris Turpin, report preparation, and a special thanks to Mr. Edward Rynaski for his thoughts on alpha response in the time domain.

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ADI = attitude director indicator

b = wing span, ft

$\bar{c}$ = mean aerodynamic chord, ft

C_D = drag coefficient = $D/\bar{q}S$

C_{D_o} = drag coefficient at zero angle of attack

C_{D_i} = $\partial C_D/\partial i$, $i = \alpha, \delta_e$, deg^{-1}

c.g. = center of gravity

C_L = lift coefficient = $L/\bar{q}S$

C_{L_o} = lift coefficient at zero angle of attack

C_{L_i} = $\partial C_L/\partial i$, $i = \alpha, \delta_e, \delta_{DLC}$, deg^{-1}

C_{L_j} = $\left(\frac{2V}{\bar{c}}\right) \partial C_L/\partial j$, $j = \dot{\alpha}, q$, deg^{-1}

C_ℓ = rolling moment coefficient = $L/\bar{q}Sb$

C_{ℓ_i} = $\partial C\ /\partial i$, $i = \beta, \delta_a, \delta_r$, deg^{-1}

C_{ℓ_j} = $\left(\frac{2V}{b}\right) \partial C\ /\partial j$, $j = p, r$, deg^{-1}

C_m = pitching moment coefficient = $M/\bar{q}S\bar{c}$

C_{m_o} = pitching moment coefficient at zero angle of attack

C_{m_i} = $\partial C_m/\partial i$, $i = \alpha, \delta_e$, deg^{-1}

C_{m_j} = $\left(\frac{2V}{\bar{c}}\right) \partial C_m/\partial j$, $j = \dot{\alpha}, q$, deg^{-1}

C_n = yawing moment coefficient = N/qSb

C_{n_i} = $\partial C_n/\partial i$, $i = \beta, \delta_a, \delta_r$, deg^{-1}

C_{n_j} = $\left(\frac{2V}{b}\right) \partial C_n/\partial j$, $j = p, r$, deg^{-1}

C_y = side force coefficient = $Y/\bar{q}S$

C_{y_i} = $\partial C_y/\partial i$, $i = \beta, \delta_a, \delta_r$, deg^{-1}

C_{y_j} = $\left(\frac{2V}{b}\right) \partial C_y/\partial j$, $j = p, r$, deg^{-1}

LIST OF SYMBOLS (Cont'd)

D	=	drag, lb
DLC	=	direct lift control
dB	=	decibel units for Bode amplitude = 20 $\log_{10}$ (amplitude)
F_{AW}	=	aileron wheel force, lb
F_{ES}	=	elevator wheel force, positive aft, lb
F_{RP}	=	rudder pedal force, lb, positive, right pedal forward
g	=	gravitational constant = 32.17 ft/sec^2
h	=	altitude of airplane c.g., ft
h_c	=	commanded change in airplane altitude at pilot station, ft
h_p	=	altitude of airplane at pilot station, ft
h_{WH}	=	altitude of airplane at model wheels, ft
h_ε	=	$(h_c - h_p)$, error between the commanded altitude and altitude at the pilot station, ft
h_T	=	altitude of airplane at TIFS wheels, ft
HSI	=	Horizontal Situation Indicator
I_{xx}, I_{yy}, I_{zz}	=	moments of inertia about X, Y, Z body axes, slug-ft^2
I_{xz}	=	product of inertia about X, Z body axes, slug-ft^2
IFR	=	Instrument Flight Rules
K_{p_h}	=	steady state pilot gain altitude loop closure, rad/ft
K_{p_θ}	=	steady state pilot gain in attitude loop closure, lb/rad
K_q	=	loop gain in pitch augmentation system, deg/deg/sec
K_α	=	angle of attack feedback gain, deg/deg
K_c	=	command gain
K_I	=	integrator gain
K_L	=	loop gain

LIST OF SYMBOLS (Cont'd)

L	=	lift, lb
L, M, N	=	moments about X, Y, Z body axes, ft-lb
m	=	mass of airplane, slugs
ms	=	milliseconds
n_y, n_z	=	lateral, normal acceleration, g's (n_y + right, n_z + down)
n_j^i	=	transfer function numerators
p, q, r	=	roll, pitch, yaw rates, deg/sec
PIOR	=	pilot-induced oscillation rating
PR	=	pilot rating
ϕ_{PC}	=	phase angle of pilot compensation, $\tan^{-1}(\tau_L \omega_{BW})$, deg
$\bar{q}$	=	dynamic pressure = $\frac{1}{2}\rho V^2$, lb/ft²
q_c	=	pitch rate command
s	=	Laplace operator, sec^{-1}
S	=	reference wing area, ft²
T	=	total thrust, lb
T_D	=	equivalent time delay from equivalent systems analysis, sec
T_z	=	lead + lag pre-filter zero
T_F	=	lead + lag pre-filter pole
T_{wo}	=	washout pre-filter pole
t_1	=	effective time delay from maximum slope intercept method, sec
$1/\tau_{\theta_2} \approx L_\alpha$	=	$\frac{g}{V}\,\frac{C_{L_\alpha}}{C_L}$
TIFS	=	Total In-Flight Simulator
Δt	=	rise from time history criteria analysis, sec
V	=	true airspeed, ft/sec

V_I	=	inertial speed, ft/sec
V_x, V_y, V_z	=	velocity components along XZ, Y, Z body axes, ft/sec
W	=	airplane weight, lb
X, Y, Z	=	body axes, X-Z plane is in plane of symmetry with X directed forward parallel to the fuselage reference line, Z directed downward, and Y directed out the right wing
X_{MP}	=	distance along X-body axis between c.g. and pilot station, ft
X_{PCR}	=	distance along X-body axis between instantaneous center of pitch rotation and pilot station, ft
Y_{c_θ}	=	aircraft θ/F_{ES} transfer function
Y_{p_h}	=	pilot describing function in altitude loop closure
Y_{p_θ}	=	pilot describing function in attitude loop closure
Z_{SP}	=	distance between pilot station and X-stability axis, negative for pilot above stability axis, ft
α	=	angle of attack, deg
α_g	=	turbulence component of angle of attack, deg
α_T	=	total angle of attack with respect to true airspeed, deg
α_I	=	inertial angle of attack (with respect to inertial velocity), deg
β	=	sideslip, deg
β_g	=	turbulence component of sideslip, deg
β_T	=	total sideslip with respect to true airspeed, deg
β_I	=	inertial sideslip (with respect to inertial velocity), deg
γ	=	flight path angle, deg
Δn_z	=	incremental normal acceleration, g's
δ_a	=	aileron surface deflection, included angle positive left T.E. down, deg

LIST OF SYMBOLS (Cont'd)

δ_{AW}	=	aileron wheel deflection, positive clockwise, deg
δ_{AWC}	=	aileron command positive left T.E. down, deg
δ_e	=	elevator surface deflection, positive T.E. down, deg
δ_{EC}	=	elevator column deflection, positive aft, inch
δ_r	=	rudder surface deflection, positive T.E. left, deg
δ_{RP}	=	rudder pedal deflection, positive right pedal forward, inch
δ_{RPC}	=	rudder, command positive T.E. left, deg
δ_{th}	=	throttle lever position, deg
$[\Delta A/\Delta\phi]_\theta$	=	slope of Bode amplitude with phase for the airplane plus pilot delay at reference frequency for pitch attitude loop, dB/deg
$\Delta\phi_\theta$	=	differential phase angle of the airplane plus pilot delay at reference frequency for pitch attitude loop, deg
ζ	=	damping ratio
ζ_d	=	damping ratio of Dutch roll mode
ζ_{ph}	=	damping ratio of phugoid mode
ζ_{sp}	=	damping ratio of short period mode
θ	=	pitch attitude, deg or rad
θ_c	=	commanded change in airplane attitude, deg or rad
θ_ε	=	$(\theta_c - \theta)$, error between commanded pitch attitude and airplane pitch attitude, deg or rad
λ	=	aperiodic real root magnitude, sec^{-1}
ρ	=	air density, $slug/ft^3$
σ_i	=	mean square gust intensity, $i = \alpha, \beta$, deg
τ_L	=	time constant of pilot's lead element, sec
τ_{pitch}	=	time constant of pitch command prefilter, sec

LIST OF SYMBOLS (Cont'd)

τ_{roll}	=	time constant of roll command prefilter, sec
τ_R	=	time constant of roll mode, sec
τ_S	=	time constant of spiral mode, sec
ϕ	=	bank angle, deg
ω_{BW}	=	bandwidth frequency, rad/sec
ω_d	=	undamped natural frequency of Dutch roll mode, rad/sec
ω_{ph}	=	undamped natural frequency of phugoid mode, rad/sec
$\omega_{n_{sp}}$	=	undamped natural frequency of short period mode, rad/sec

SUBSCRIPTS

c.g.	=	center of gravity
DLC	=	direct lift control
e	=	equivalent parameter from equivalent system analysis
g	=	turbulence component
G.E.	=	ground effect
I	=	inertial quantity
m	=	model quantity
MGP	=	model gear to pilot
MGR	=	model gear to TIFS radar altimeter
MP or PM	=	model quantity at pilot station
MTCG	=	model quantity transformed to TIFS c.g.
P	=	quantity at pilot station
TIFS or unsubscripted	=	TIFS quantity at its c.g.
WH	=	model wheel height
$m_{c.g.}$	=	model center of gravity
stab	=	stability axis

Section 1
INTRODUCTION

The objective of this in-flight research program, utilizing the Air Force Wright Aeronautical Laboratory Total In-Flight Simulator (TIFS), was to generate flying qualities data that will allow better definition of design criteria for pitch rate command systems as applied to the flared landing task. The landing task was performed to evaluate a generic transport (193,000 lb. gross) with static instability (time to double amplitude 2 sec.), that was augmented with various flight control system configurations. The lateral/directional model was augmented to Level 1 flying qualities and was fixed for the entire program.

The experiment considered variations in short period frequency (1.8 and 2.8 rad/sec) and $1/\tau_{\theta_2}$ (0.4, 0.7, and 1.0). The following factors were considered in the flight control system (FCS):

- Pitch rate feedback with proportional and integral forward paths. Rate command design.
- A lead/lag pre-filter added to increase the response at frequencies higher than $1/\tau_{\theta_2}$.
- "Superaugmentation" (i.e., high levels of proportional and integrator gain).
- Lead/lag prefilter applied to Superaugmentation.
- Neutral static stability (first order pitch rate response).
- Angle of attack and pitch rate feedback to provide Level 1 conventional aircraft response.

- A command path wash-out pre-filter to provide monotonic (conventional) pitch stick forces in the flare by reducing the response of the rate command design at frequencies lower than ω = .2 rad/sec.

Also considered were the "shuttle like" models combined with various shuttle flight control system concepts. Application of the command path wash-out filter to a number of the "shuttle like" configurations was also tested.

Two NASA evaluation pilots participated in this program. The NASA Dryden pilot evaluated all configurations. The NASA Langley pilot evaluated all non-shuttle configurations and four shuttle configurations.

Pilot comments and ratings were recorded in flight. This data is considered as the principal data obtained from this program. In addition, model responses and data pertinent to trajectory analysis were recorded.

The configurations were presented to the pilots in an order that mixed good and bad configurations so as to inhibit bias. Repeat evaluations of configurations were performed where pilot rating disparity existed or in areas where interest developed during the experiment (i.e., in order to verify unexpected trends etc.).

A total of twenty seven configurations were tested. These were constructed from seven aerodynamic models:

1. $1/\tau_{\theta_2}$ = 0.4
2. $1/\tau_{\theta_2}$ = 0.7
3. $1/\tau_{\theta_2}$ = 1.0
4. Neutral static stability with $1/\tau_{\theta_2}$ = 0.4
5. Neutral static stability with $1/\tau_{\theta_2}$ = 0.7
6. Shuttle like
7. Shuttle like, with canard

and eight pitch axis flight control systems:

1. Proportional plus integrated pitch rate feedback, low $\omega_{n_{sp}}$
2. Proportional plus integrated pitch rate feedback, high $\omega_{n_{sp}}$
3. Superaugmented
4. Conventional Augmentation (α and q feedback)
5. Calspan Shuttle FCS
6. Modified Shuttle FCS
7. OFT Shuttle FCS
8. Calspan Shuttle FCS plus time delay
   (equivalent to body bending filter in forward loop)

Various combinations of the above models and flight control systems, with selected application of the pre-filter, and wash-out filter comprised the twenty seven tested configurations. All configurations were flown at the same flight condition; 132 KTS IAS, model flaps 50° and gear down. The task consisted of a VFR approach and landing to touch down.

More detailed descriptions of the configurations which were evaluated are outlined and illustrated in Section 2 along with other details of the experiment design. Section 3 presents the mechanization of the experiment including the description of the TIFS setup. Section 4 presents the results of the program, including data collected and analysis. Section 5 contains the conclusions. Appendix M contains a full set of figures. Selected figures are presented in the text of the report, consequently the numbers of these selected figures may not be continuous.

Section 2
EXPERIMENT DESIGN

2.1 CONFIGURATION DESCRIPTION

The experiment consisted of eight configuration sets that made up a total of twenty seven configurations which were flight tested. The configuration numbering system was made up of three to four digits:

```
   ┌─Configuration Set Number
   │   ┌──Sequence Within Set
   │   │   ┌───Aircraft Model
   │   │   │   ┌────Command Path Mods (1 = wash-out prefilter)
   X - X - X - X
```

2.1.1 Configuration Development

A general purpose flight control system was developed in analog form for the experiment and is shown in Figure 1 and further described in Section 2.1.3. Selection of switch positions and gain changes allowed for all the variations required for the experiment. Feedback and loop gains were adjusted to provide the level of augmentation desired. In addition, a bank angle and velocity feedback was available to automatically command the elevator deflection required for level turns. Command path variations provided for changes in command gain (K_c), addition of transport time delays (T_1), a wash-out filter (which converted rate command to angle of attack command at low frequency for the landing flare), and a lead/lag prefilter (used to position a pole to cancel the control system zero and to place a zero so as to restore $1/\tau_{\theta_2}$ in selected configurations, i.e., cancel the λ_2' root near $1/\tau_{\theta_2}$).

The digital aerodynamic model was of a generic transport with a gross weight of 193,000 lbs at 132 KIAS gear down and 50° flaps. The basic model was modified into seven aerodynamic configuration models:

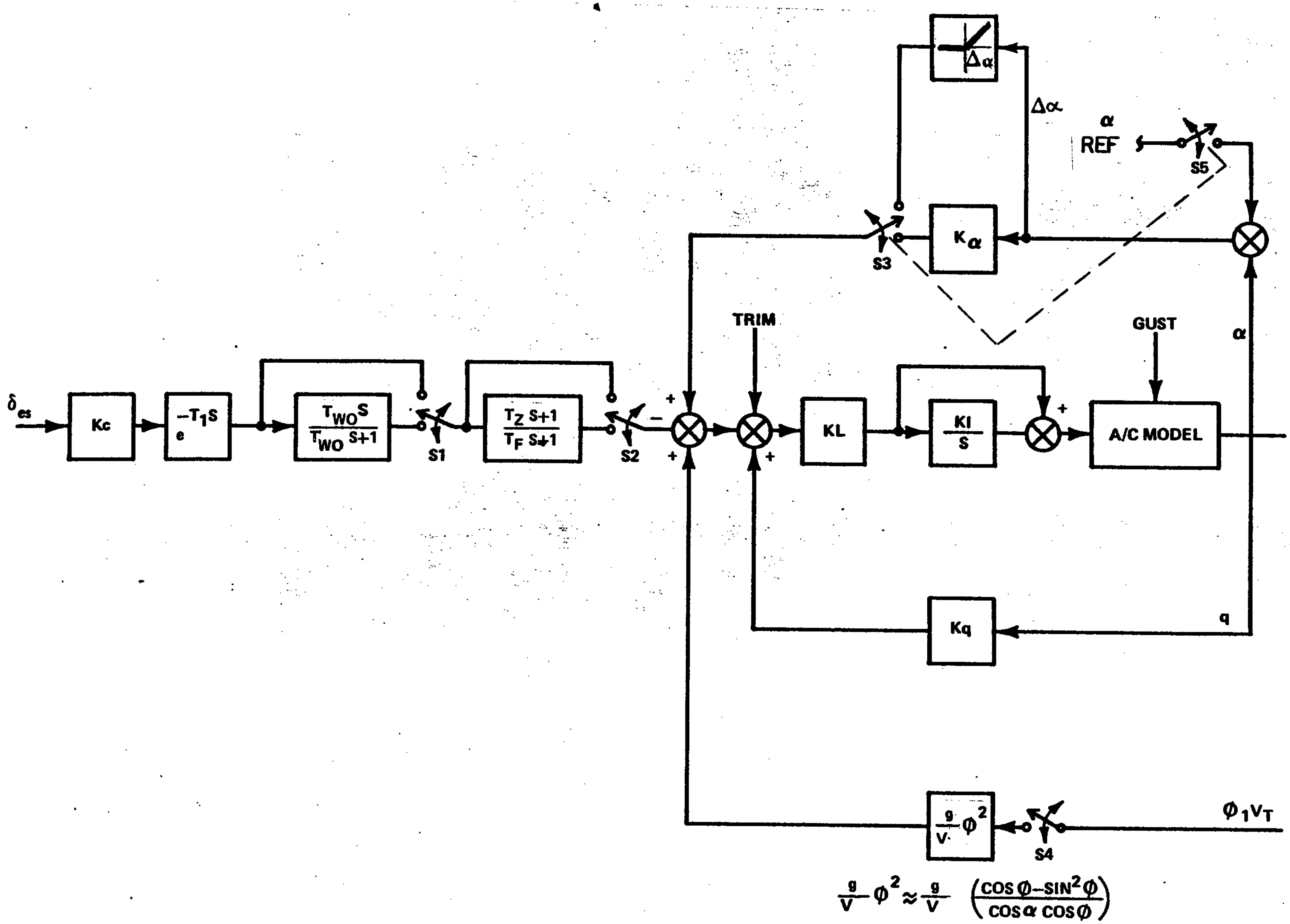


Figure 1 PITCH RATE CRITERIA FLIGHT CONTROL SYSTEM

Aerodynamic Model No.	Description	Major Change to Achieve Modification
1	Basic with $1/\tau_{\theta_2} = 0.4$	C_{L_α}
2	Basic with $1/\tau_{\theta_2} = 0.72$	C_{L_α}
3	Neutral static stability with $1/\tau_{\theta_2} = 0.4$	C_{L_α} and C_{M_α}
4	Neutral static stability with $1/\tau_{\theta_2} = 0.72$	C_{L_α} and C_{M_α}
5	Shuttle like ($1/\tau_{\theta_2} = 0.4$)	C_{L_α} and $C_{L_{\delta_e}}$
6	Shuttle like canard ($1/\tau_{\theta_2} = 0.4$)	C_{L_α} and $C_{L_{\delta_e}}$
7	Basic with $1/\tau_{\theta_2} = 1.0$	C_{L_α}

A combination of these seven aircraft digital models plus variations in the analog flight control system (flight control system variations will be discussed in paragraphs 2.1.3 - 2.1.10) provided the twenty seven flight tested configurations.

engaged. Model time history overlays were used to verify the model on the on-board strip chart and TIFS model following was monitored throughout the evaluation. In addition, the step response was recorded using the on-board digital recorder. During post flight analysis all configurations were re-verified using the recorder data. As an example, on flight 744, the last data flight, a shuttle configuration was flown back to back with the same configuration using the wash-out filter. The addition of the wash-out filter raised the handling qualities rating from a seven to a three. In order to verify that the only difference in the two configurations was the wash-out filter the TIFS motion responses to the test inputs were stripped from the data tape and compared to the computer time histories. The comparison verified the configurations. Any subsequent configurations that were in question were verified by the same method.

2.1.3 Set 1 Configurations

The set consisted of three "conventional" pitch rate feedback configurations with proportional plus integral paths: These configurations exhibit minimal pitch rate overshoot (and subsequent sluggish angle of attack response). The loop gain (K_L) was set at 4.0 which resulted in a nominal short period of $\omega_n = 2.8$ and $\zeta \simeq 0.8$ as $1/\tau_{\theta_2}$ was set at three levels; 0.38, 0.72, and 1.0 (n_z/α 2.6, 5.0, and 6.4 respectively).

The short period dynamics for the experiment were picked from within Level 1 boundaries of the short period frequency requirements Class III, Category C flight phase (MIL-F-8785C) at the (n_z/α) levels that were chosen (Figure 2). These dynamics were obtained from a single flight control system implementation by changing loop gain (K_L). (See Appendix I, Root Locus Plots).

The range of values for $1/\tau_{\theta_2}$ for most aircraft in power approach is from ~ 0.3 to 1.0, with the majority falling from 0.5 to 0.7. Consequently the low value of $1/\tau_{\theta_2}$ chosen for this experiment was 0.38 ($n_z/\alpha = 2.6$) which is near the shuttle value. The mid range value was chosen at 0.72 (n_z/α = 5.0) because it matches the NT-33 and Calspan Learjet and could be correlated with data from those in-flight simulators. A high value of 1.0 ($n_z/\alpha = 6.4$) was chosen as a reasonable upper limit.

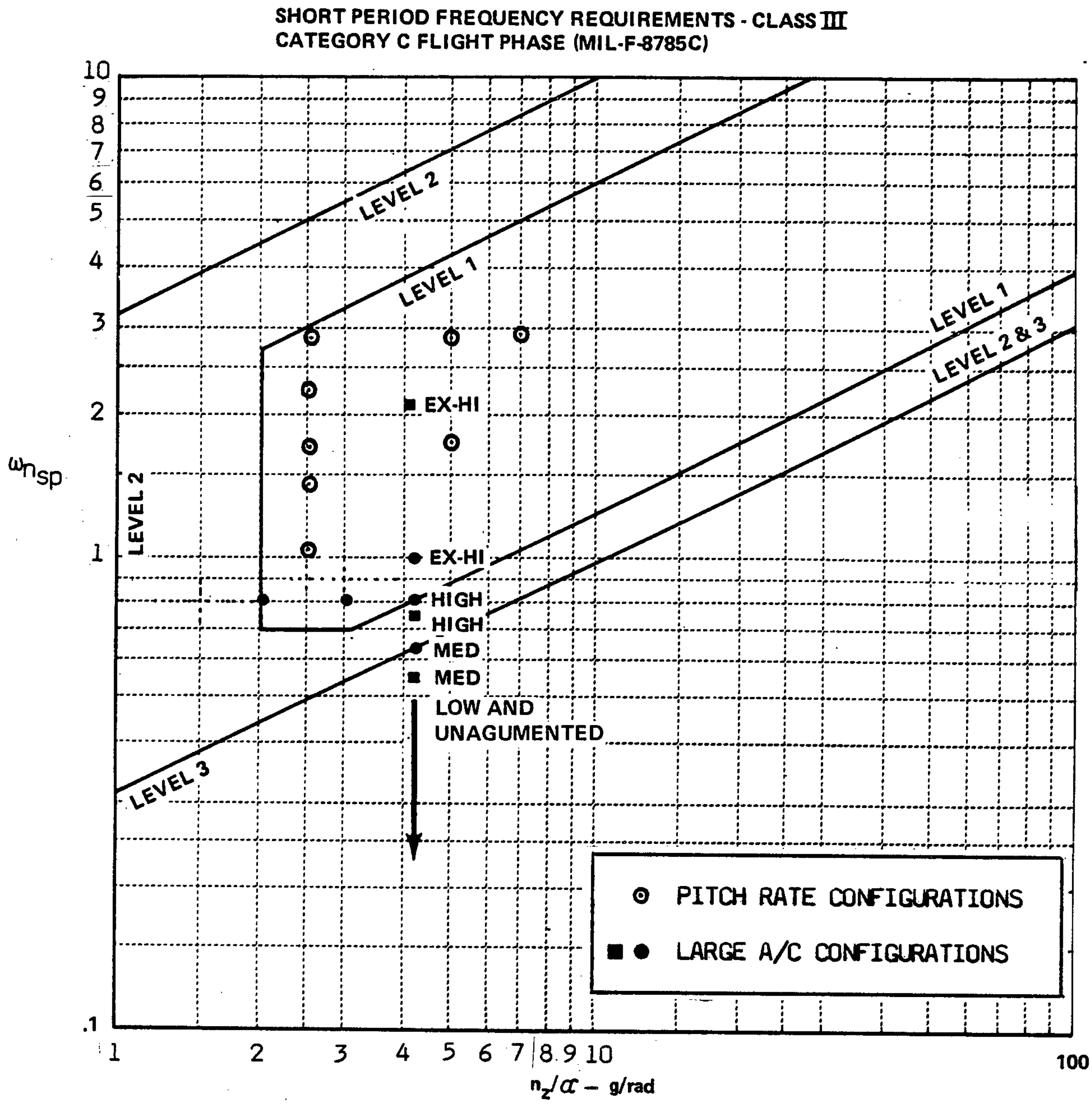
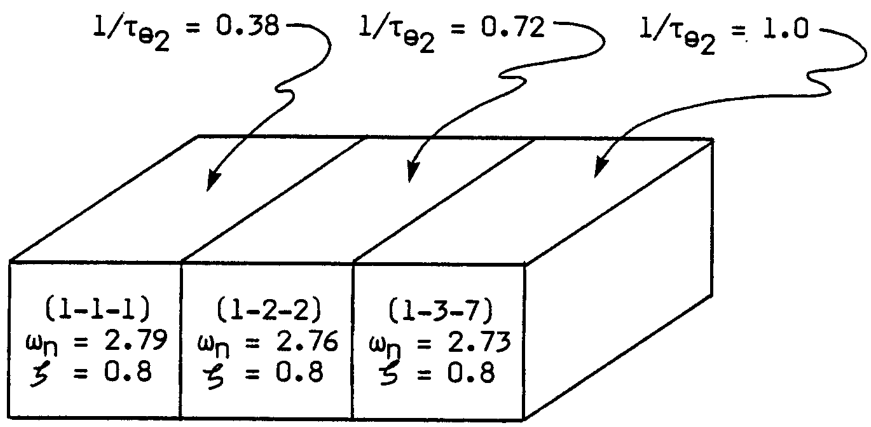
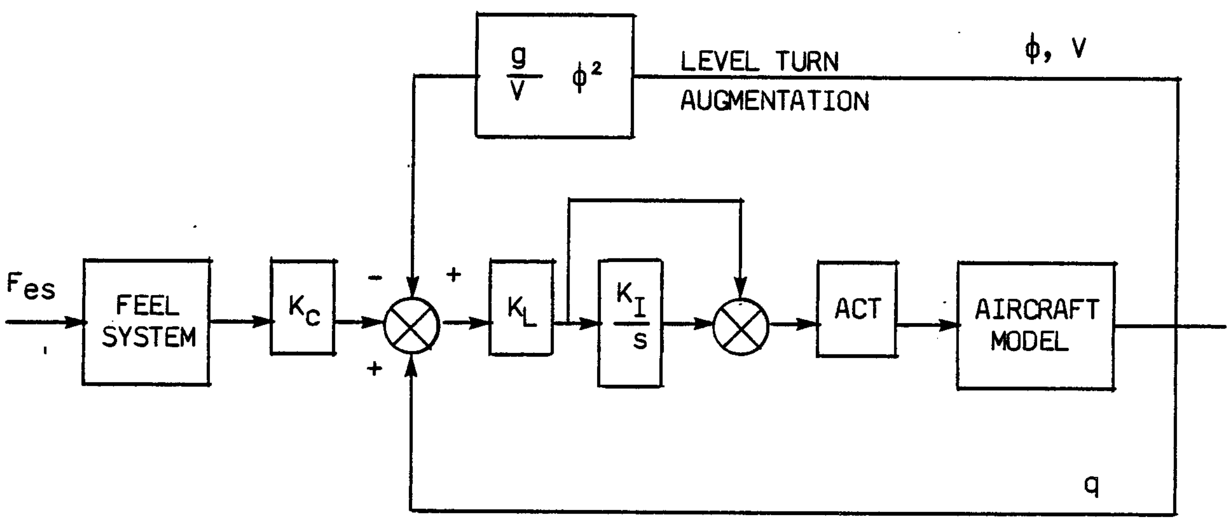


Figure 2 AUGMENTATION LEVELS VS ω_{SP} REQUIREMENTS - NOMINAL ROOTS

SET 1 MATRIX



SET 1 FLIGHT CONTROL SYSTEM

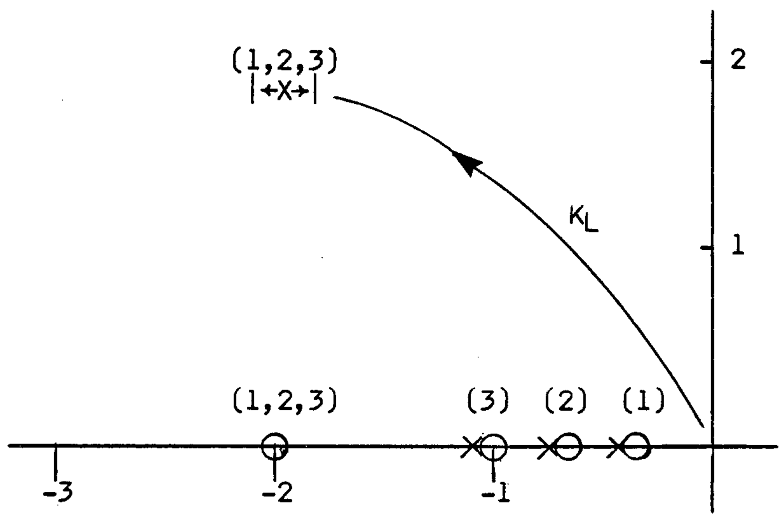


SET 1 TABLE SUMMARY

Config	$\omega_{n_{sp}}$	ζ_{sp}	$1/\tau_{\theta_2}$	λ_2'	K_C	K_L	K_I	A/C Model
1-1-1	2.79	0.8	0.38	0.44	1.8	4	2	1
1-2-2	2.76	0.8	0.72	0.82	1.8	4	2	2
1-3-7	2.73	0.8	1.0	1.19	1.8	4	2	7

SET 1 ROOT LOCUS PLOTS

(Simplified, low residue near origin deleted for clarity)

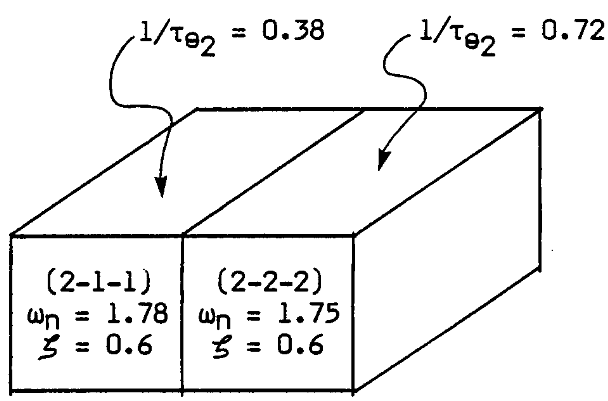


[See Appendices A, B, and C for time histories, Bode plots, and transfer functions]

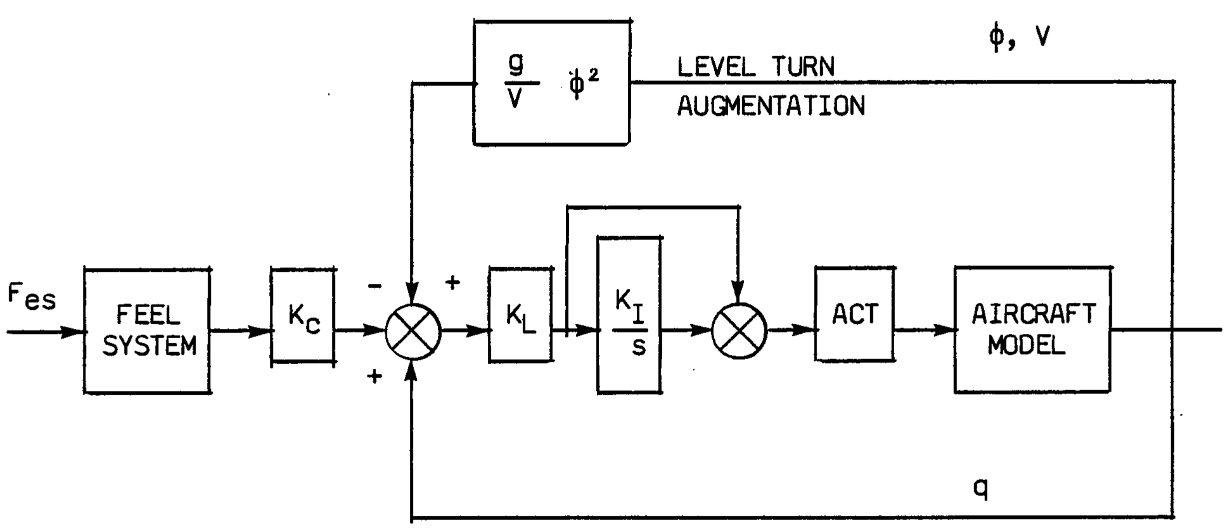
2.1.4 Set 2 Configurations

This set consisted of two configurations obtained from the same flight control system as set 1 but at a lower loop gain (i.e., 2.0). This resulted in a nominal short period of $\omega_n \approx 1.8$, $\zeta \approx 0.6$ as $1/\tau_{\theta_2}$ was set at 0.38 and 0.72.

SET 2 MATRIX



SET 2 FLIGHT CONTROL SYSTEM

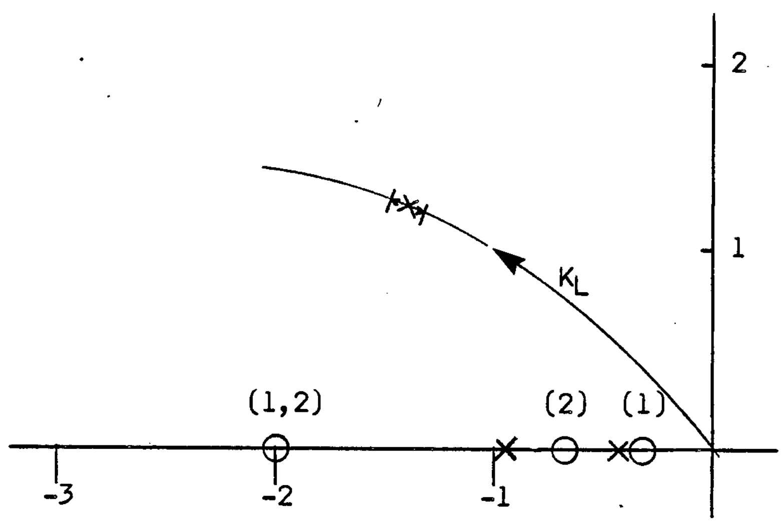


SET 2 TABLE SUMMARY

Config	$\omega_{n_{sp}}$	ζ_{sp}	$1/\tau_{\theta_2}$	λ_2'	K_C	K_L	K_I	A/C Model
2-1-1	1.78	0.6	0.38	0.5	1.8	2	2	1
2-2-2	1.75	0.6	0.72	0.93	1.8	2	2	2

SET 2 ROOT LOCUS PLOTS

(Simplified, low residue near origin deleted for clarity)

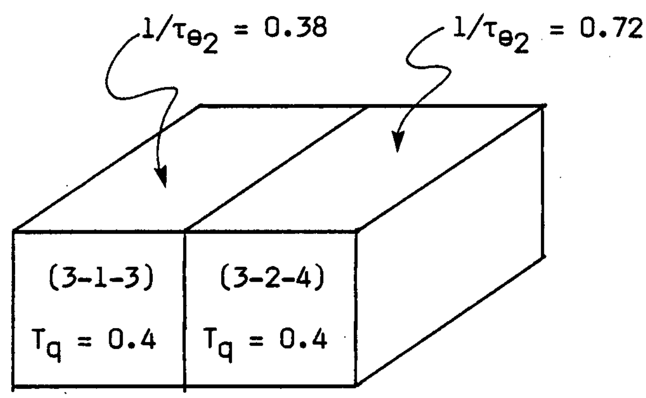


[See Appendices A, B, and C for time histories, Bode plots, and transfer functions]

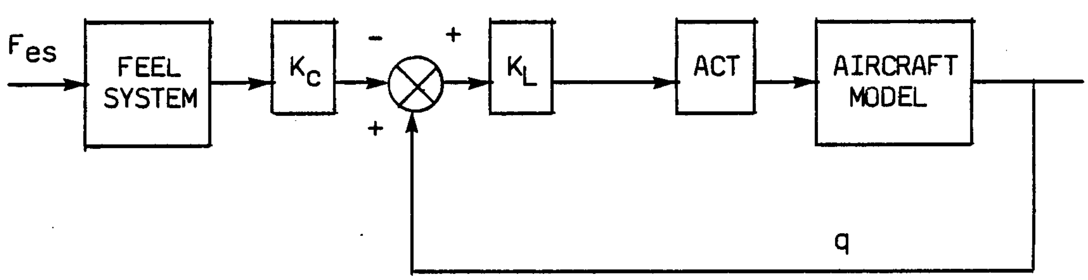
2.1.5 Set 3 Configurations

This was a neutral static stability set obtained by removing the integrator in the forward path and modifying the aircraft model. The first order pitch rate time constant was 0.4 secs. $1/\tau_{\theta_2}$ was set at 0.38 and 0.72. Level turn augmentation (ϕ^2 feedback) was not used.

SET 3 MATRIX



SET 3 FLIGHT CONTROL SYSTEM

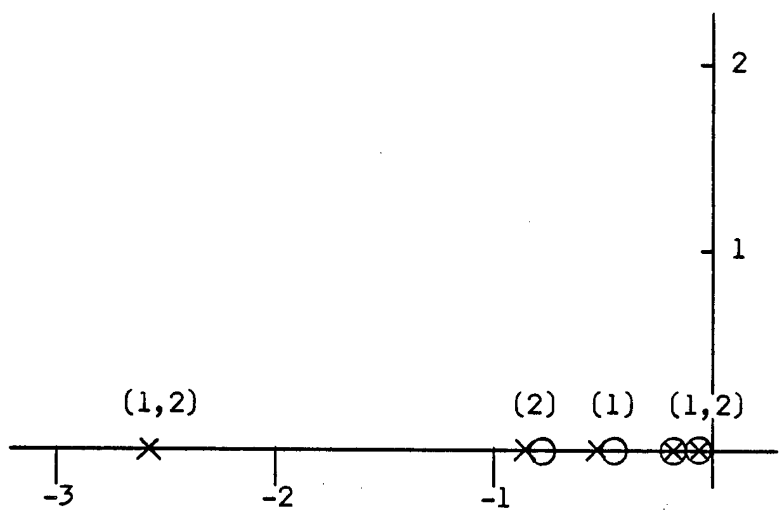


SET 3 TABLE SUMMARY

Config	T_q	$1/\tau_{\theta_2}$	λ_2'	K_c	K_L	K_I	A/C Model
3-1-3	0.4	0.38	0.25	1.8	2	0	3
3-2-4	0.4	0.72	0.25	1.8	2	0	4

SET 3 ROOT LOCUS PLOTS

(Simplified, low residue near origin deleted for clarity)



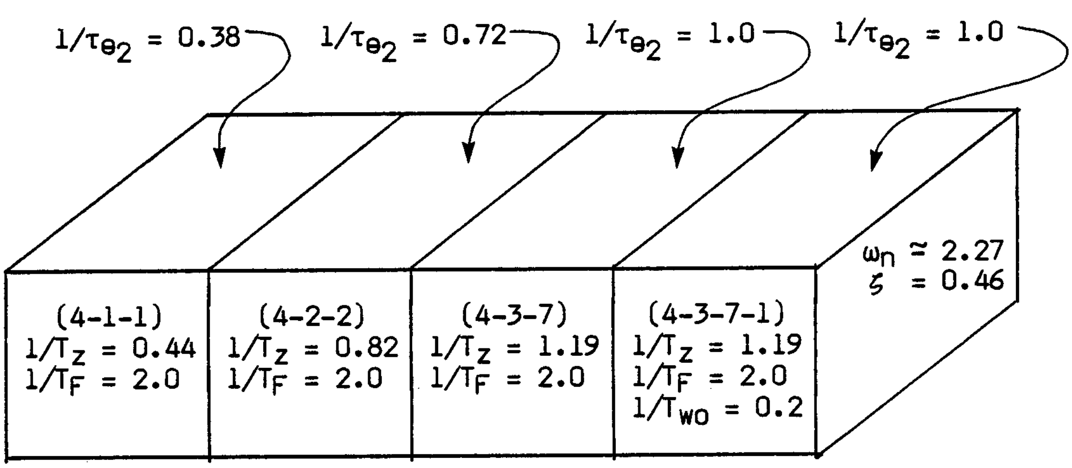
[See Appendices A, B, and C for time histories, Bode plots, and transfer functions]

2.1.6 Set 4 Configurations

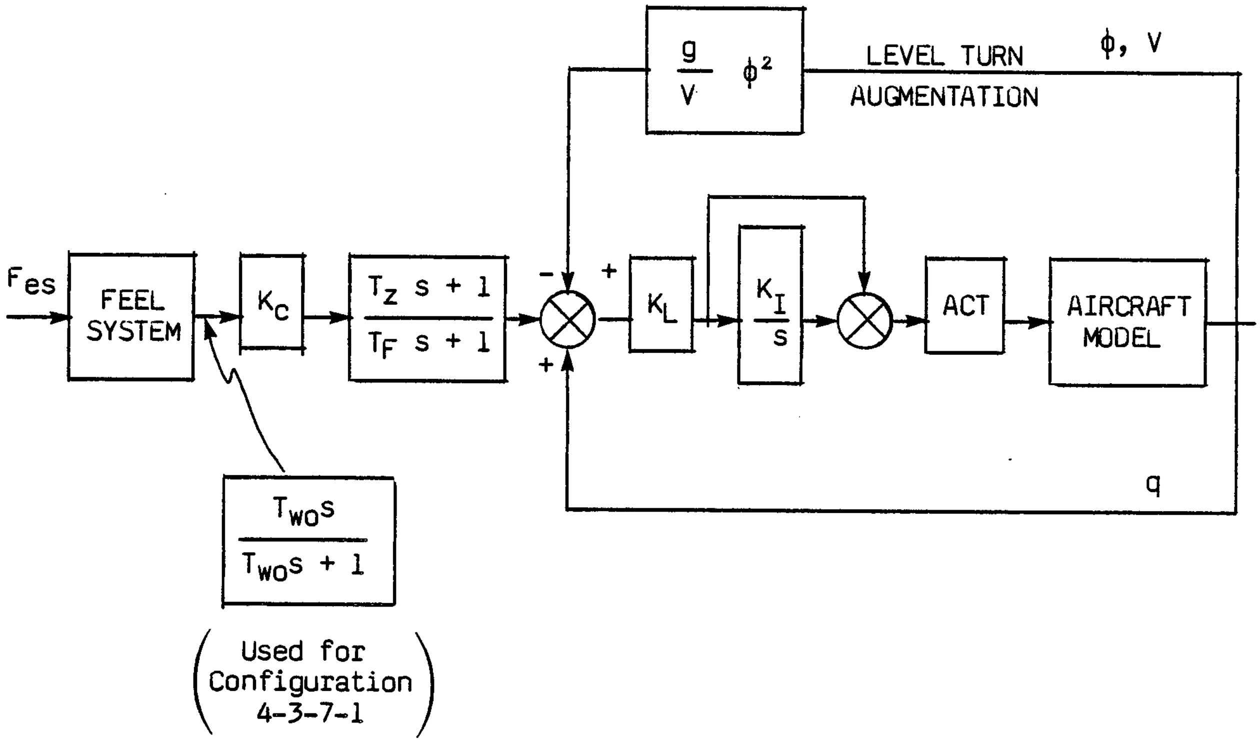
Set 4 was a repeat of 1-1-1, 1-2-2, and 1-3-7 with the addition of the Calspan lead/lag prefilter that restores the $1/\tau_{\theta_2}$ zero and cancels the K_I zero. The result is a more "airplane like" pitch rate overshoot which provides a more brisk angle of attack response. The pre-filter configurations required a reduction in K_C (command gain) in order to normalize pitch sensi tivity i.e., $M_{F_{es}} = \frac{\delta_{es}}{F_{es}} K_L \frac{T_z}{T_F} K_L M_{\delta_e}$ = const.

Configuration 4-3-7-1 added the Calspan washout filter to the command path of the flight control system. This filter put a zero at the origin and a real root at a typical phugoid magnitude. The result was that the pilot could use monotonic pitch stick flare forces in the landing flare rather than having to reverse pitch stick forces as required by classical rate command/attitude hold systems.

SET 4 MATRIX



SET 4 FLIGHT CONTROL SYSTEM

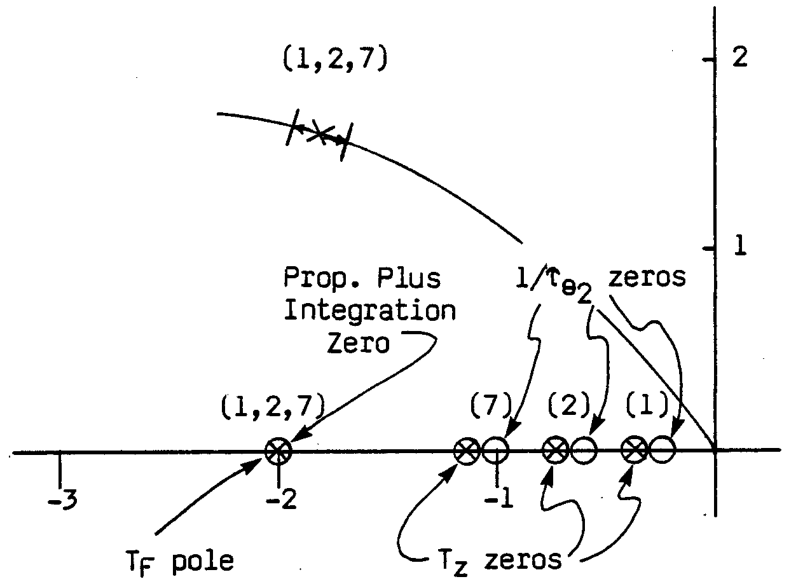


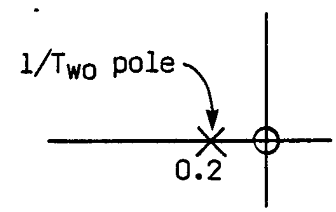
SET 4 TABLE SUMMARY

Config	ω_n	ζ	$1/\tau_{\theta_2}$	λ_2'	K_c	K_L	K_I	$1/T_Z$	$1/T_F$	$1/T_{wo}$	A/C Model
4-1-1	2.79	0.8	0.38	0.44	0.4	4	2	0.435	2	-	1
4-2-2	2.76	0.8	0.72	0.82	0.8	4	2	0.821	2	-	2
4-3-7	2.73	0.8	1.0	1.19	1.0	4	2	1.190	2	-	7
4-3-7-1	2.73	0.8	1.0	1.19	1.0	4	2	1.190	2	0.2	7

SET 4 ROOT LOCUS PLOTS

(Simplified, low residue near origin deleted for clarity)





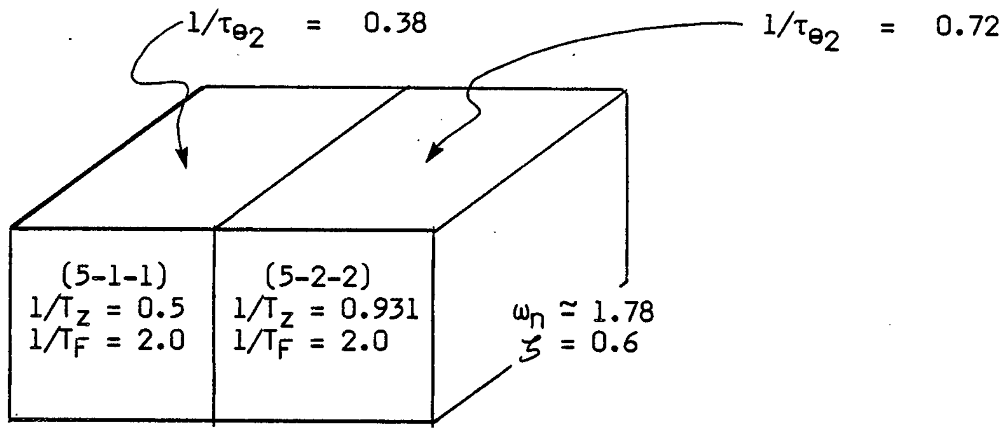
Washout Filter

[See Appendices A, B, and C for time histories, Bode plots, and transfer functions]

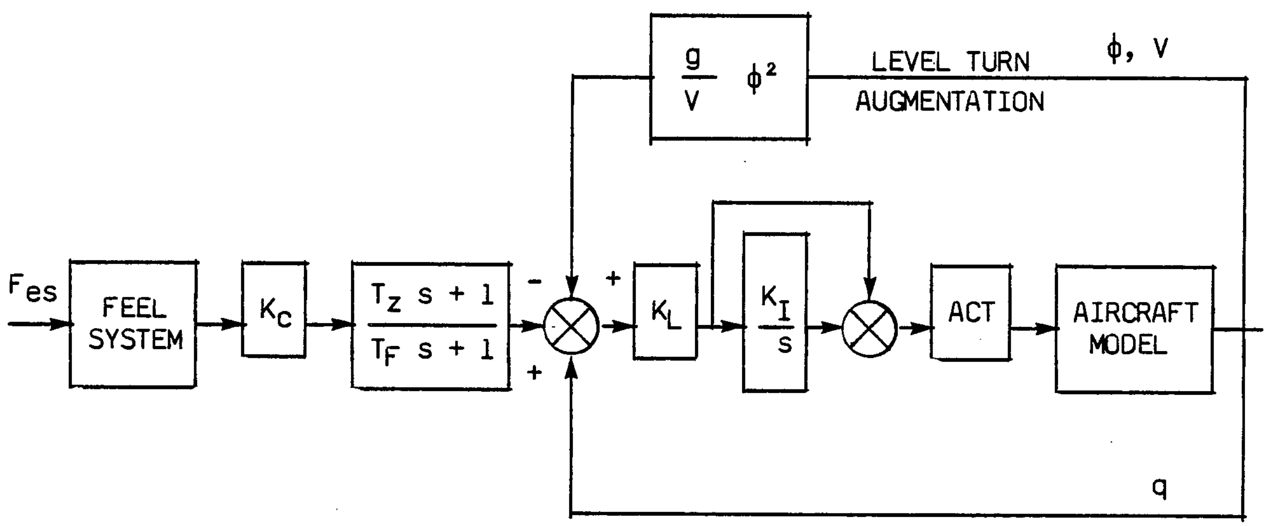
2.1.7 Set 5 Configurations

Set 5 was a repeat of 2-1-1, and 2-2-2 with the addition of the lead/lag pre-filter. As in the "pre-filter" configurations command gain (K_C) was reduced to normalize pitch sensitivity.

SET 5 MATRIX



SET 5 FLIGHT CONTROL SYSTEM

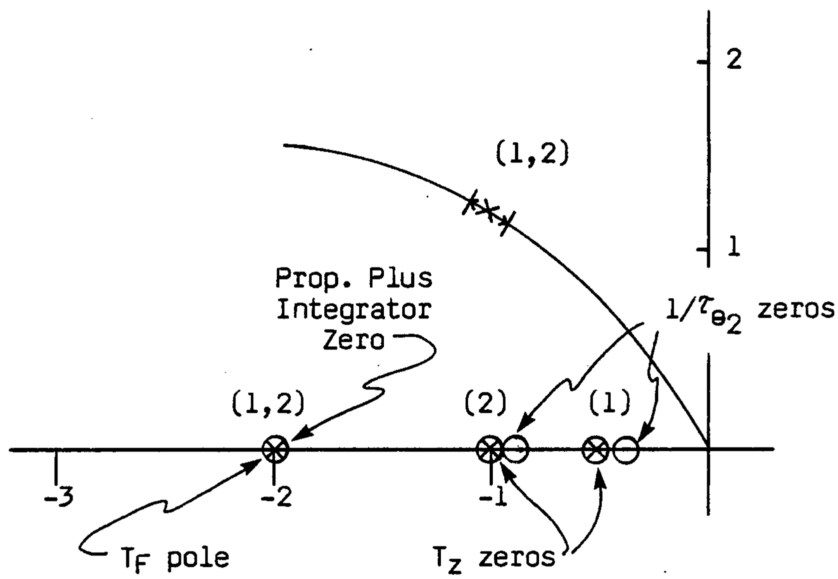


SET 5 TABLE SUMMARY

Config	ω_n	ζ	$1/\tau_{\theta_2}$	λ_2'	K_C	K_L	K_I	$1/T_Z$	$1/T_F$	A/C Model
5-1-1	1.78	0.6	0.38	0.5	0.5	2	2	0.5	2	1
5-2-2	1.75	0.6	0.72	0.93	0.9	2	2	0.931	2	2

SET 5 ROOT LOCUS PLOTS

(Simplified, low residue near origin deleted for clarity)

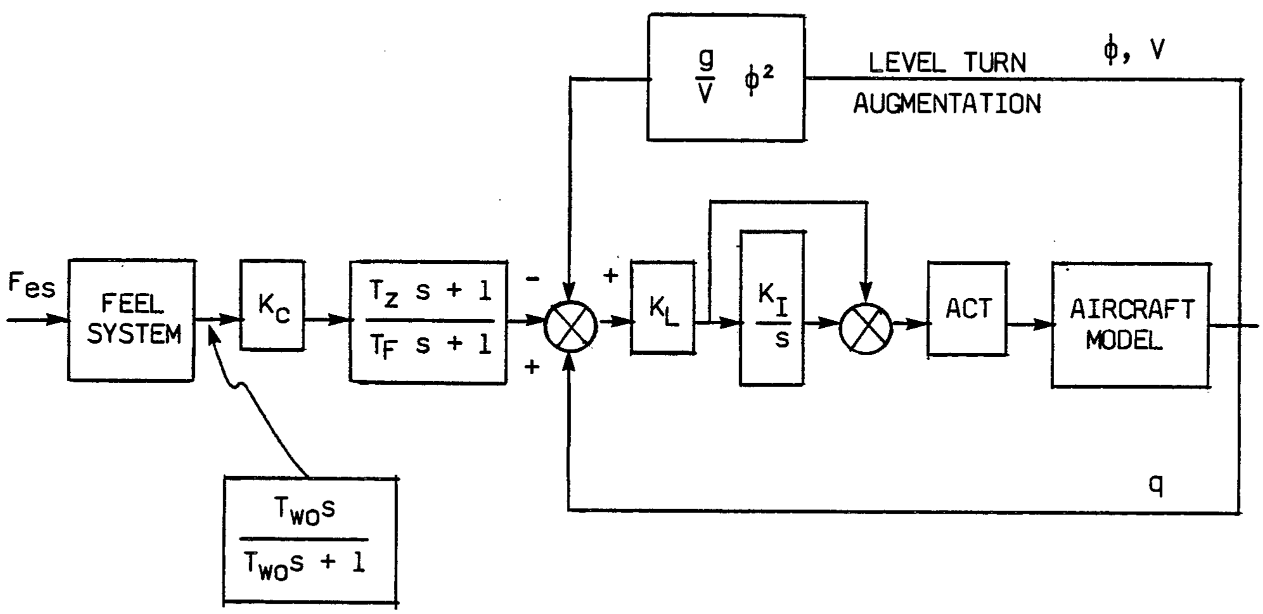


See Appendices A, B, and C for time histories, Bode plots, and transfer functions

2.1.8 Set 6 Configurations

Configuration 6-1-1 was a "superaugmented" configuration i.e., high proportional plus integrator gain in the flight control system forward loop. Configuration 6-1-1-1 added the washout filter to the command path. Configuration 6-2-1 adds the lead/lag prefilter which cancels the control system zero at K_I and restores the $1/\tau_{\theta_2}$ zero (command gain K_c was reduced to normalize pitch sensitivity). Configuration 6-2-1-1 added the washout filter to the command path, to the 6-2-1 configuration.

SET 6 FLIGHT CONTROL SYSTEM



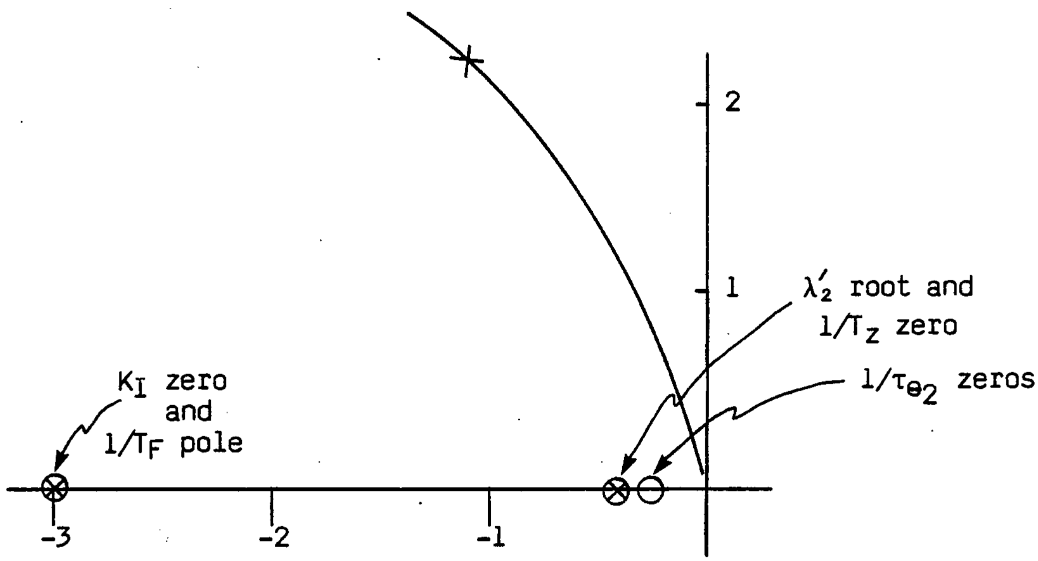
(For configurations 6-1-1-1 and 6-2-1-1)

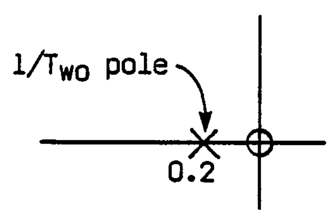
SET 6 TABLE SUMMARY

Config	ω_n	ζ	$1/\tau_{\theta_2}$	λ_2'	K_c	K_L	K_I	$1/T_z$	$1/T_F$	$1/T_{wo}$	A/C Model
6-1-1	2.27	0.46	0.38	0.45	1.4	2	3	-		-	1
6-1-1-1	2.27	0.46	0.38	0.45	1.8	2	3	-		0.2	1
6-2-1	2.27	0.46	0.38	0.45	0.45	2	3	0.448	3	-	1
6-2-1-1	2.27	0.46	0.38	0.45	0.45	2	3	0.448	3	0.2	1

SET 6 ROOT LOCUS PLOTS

(Simplified, low residue near origin deleted for clarity)





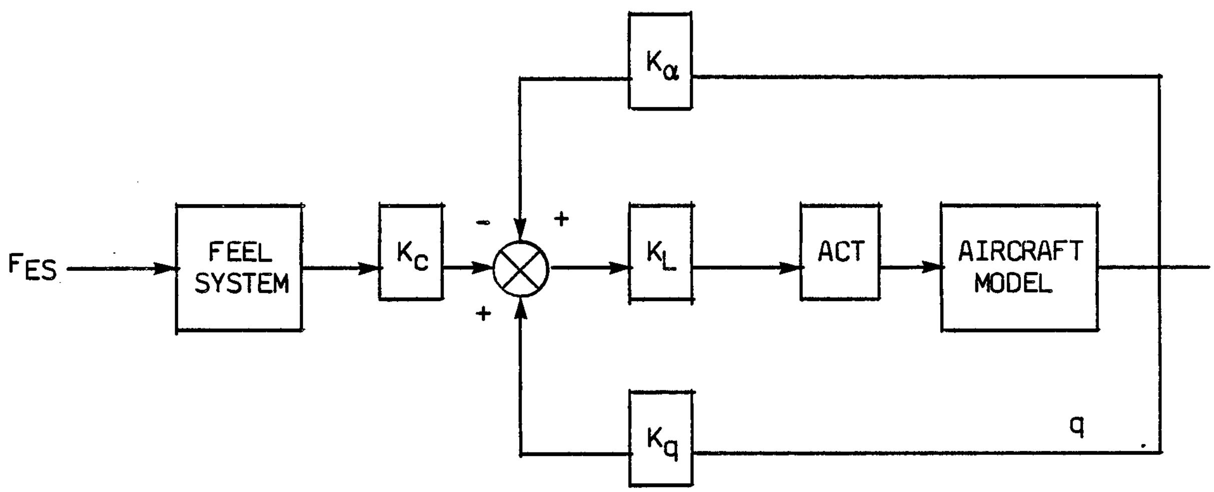
Washout Filter

[See Appendices A, B, and C for time histories, Bode plots, and transfer functions]

2.1.9 Set 7 Configurations

Configuration 7-1-4 was a "conventional" aircraft configuration that was known to be Level 1. It was obtained by using angle of attack and pitch rate feedback to one of the neutral static stability aircraft models. Turn compensation was not used.

SET 7 FLIGHT CONTROL SYSTEM

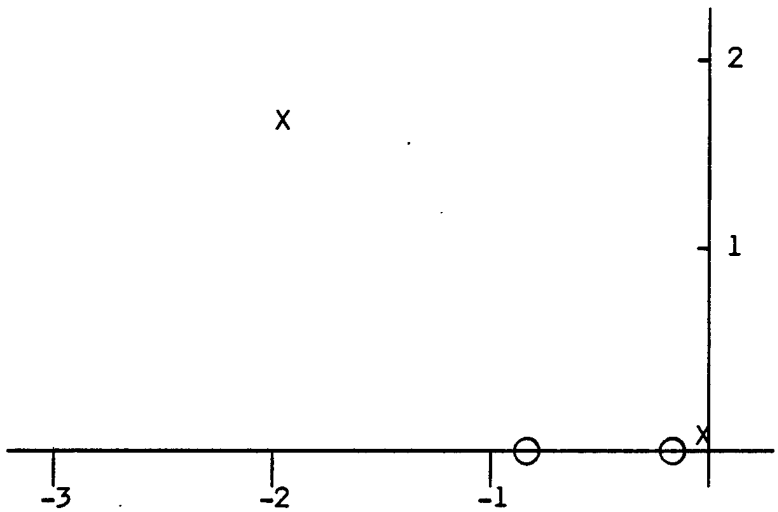


SET 7 TABLE SUMMARY

Config	ω_n	ζ_{sp}	ω_{n_p}	ζ_p	$1/\tau_{e_2}$	K_c	K_L	K_α	K_q	A/C Model
7-1-4	2.84	0.8	0.16	0.01	0.72	6.0	1.0	4.5	2.0	4

SET 7 ROOT LOCUS PLOTS

(Simplified, low residue near origin deleted for clarity)



[See Appendices A, B, and C for time histories, Bode plots, and transfer functions]

2.1.10 Set 8 Configurations

Set 8 consisted of five basic configurations. Four of these were modified with the washout filter for a total of nine configurations flown in this set. The 5 basic configurations were "shuttle orbiter like" in that the aircraft models exibited a $1/\tau_{\theta_2}$ value of 0.40 (close to the shuttle), and 4 of the models had L_{δ_e} values that placed the pilot approximately 10 feet behind the center of pitch rotation. The other Set 8 model was a "shuttle like" canard configuration with an L_{δ_e} value that placed the pilot 54 feet in front of the pitch rotation center (this assumed a canard that placed the rotation center near the shuttle center of gravity).

Configuration 8-1-5 and 8-1-5-1

Configuration 8-1-5 was a Calspan design for a shuttle flight control system similar to that presented in Reference 1. It uses the same augmented short period values of frequency and damping as the shuttle OFT flight control

system but has less time delay and incorporates the pre-filter in the command path to cancel the λ'_2 root and thus restore the effect of the $1/\tau_{\theta_2}$ zero. Configuration 8-1-5-1 added the washout filter to the command path to provide monotonic pitch stick forces during the landing flare.

Configurations 8-2-5 and 8-2-5-1

Configuration 8-2-5 was an alternate shuttle flight control system that consisted of a lower augmented short period frequency and incomplete cancellation of the λ'_2 root. This was intended to be similar to the NASA Dryden shuttle flight control system of Reference 1 but did not incorporate all of the effects of the Dryden lead/lag filter in the feedback loop. The effect was to slow the response significantly. Configuration 8-2-5-1 added the washout filter to the command path.

Configuration 8-3-5 and 8-3-5-1

Configuration 8-3-5 consisted of equivalent pole/zero locations of the shuttle OFT system. This was achieved by using the command path lead/lag filter to cancel and place roots in appropriate locations. In addition, 47 milliseconds of transport time delay was added to the command path to provide the total 220 millisecond time delay of the shuttle OFT. Configuration 8-3-5-1 added the washout filter to the command path.

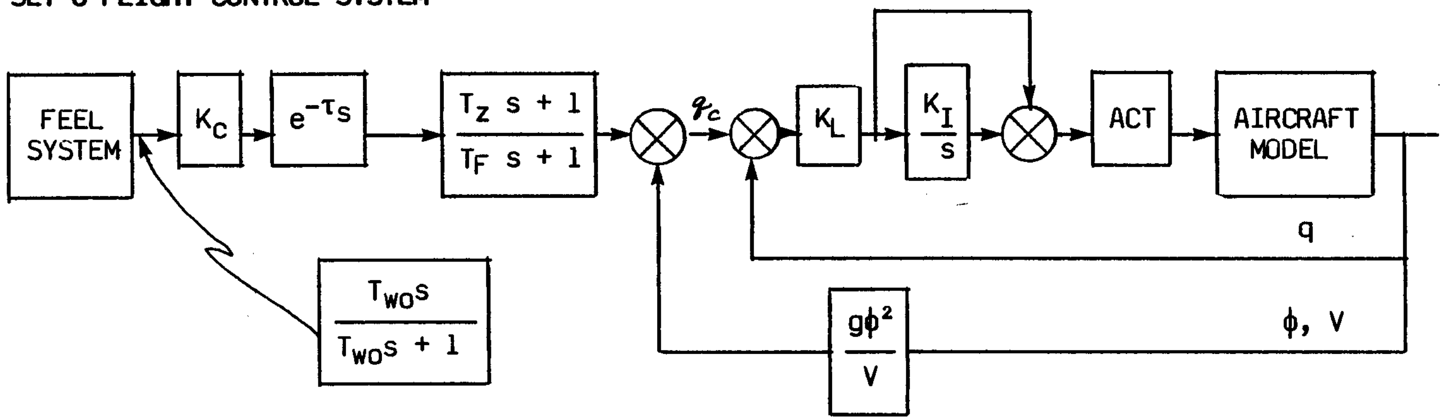
Configuration 8-4-6

This configuration consisted of the Calspan shuttle flight control system (configuration 8-1-5) with an aircraft model that was canard configured. The basic difference between this and the other shuttle models was the change in location of pitch rotation center from 10 feet in front of the pilot (for the conventional shuttle) to 54 feet behind the pilot (for the canard configuration).

Configuration 8-5-5

This configuration was the same as 8-1-5 (Calspan Design) with a time delay of 35 milliseconds added to the command path to simulate a shuttle body bending filter in the forward loop.

SET 8 FLIGHT CONTROL SYSTEM



For 8-X-X-1
Configurations

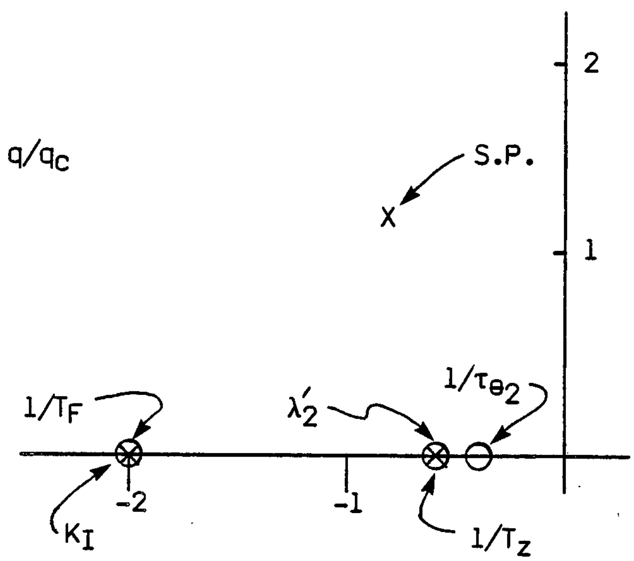
SET 8 TABLE SUMMARY

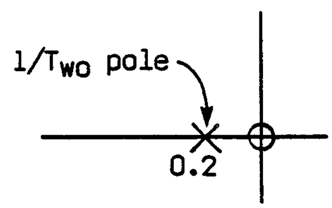
Config	$\omega_{n_{sp}}$	ζ_{sp}	$1/\tau_{\theta_2}$	λ_2'	K_C	K_L	K_I	τ	$1/T_Z$	$1/T_F$	$1/T_{WO}$	A/C Model
8-1-5	1.45	0.5	0.4	.586	0.7	1.5	2	0	0.6	2	-	5
8-1-5-1	1.45	0.5	0.4	.586	0.7	1.5	2	0	0.6	2	0.2	5
8-2-5	1.09	0.5	0.4	.70	0.9	1.0	2	0	1.0	2	-	5
8-2-5-1	1.09	0.5	0.4	.70	0.9	1.0	2	0	1.0	2	0.2	5
8-3-5	1.45	0.5	0.4	.586	0.9	1.5	2	.047	1.5	2	-	5
8-3-5-1	1.45	0.5	0.4	.586	0.9	1.5	2	.047	1.5	2	0.2	5
8-4-6	1.47	0.6	0.4	.590	0.9	1.5	2	0	0.6	2	-	6
8-5-5	1.45	0.5	0.4	.586	0.9	1.5	2	.035	0.6	2	-	5

SET 8 ROOT LOCUS PLOTS

(Simplified low residue near origin deleted for clarity).

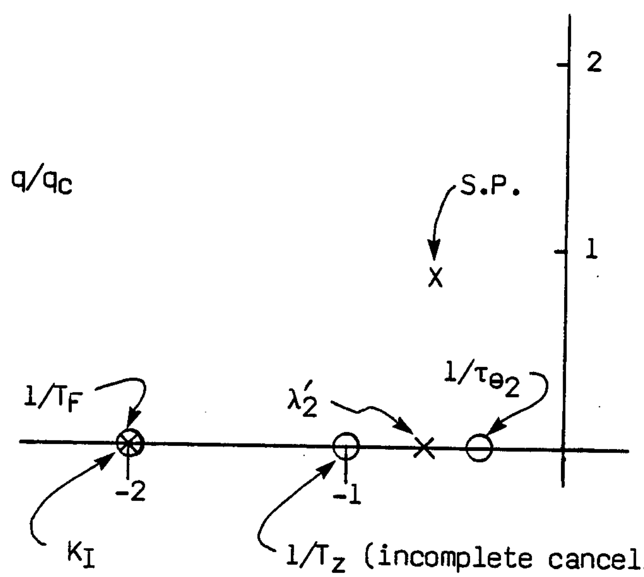
Configurations 8-1-5, 8-1-5-1, 8-4-6, and 8-5-5



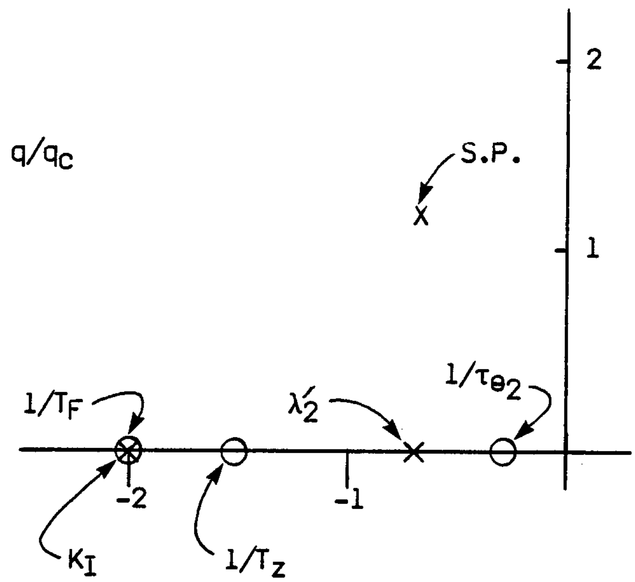


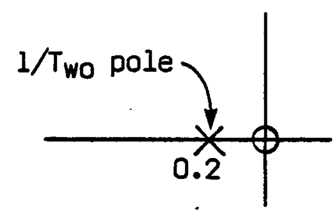
Washout Filter

Configurations 8-2-5 and 8-2-5-1



Configurations 8-3-5 and 8-3-5-1





Washout Filter

[See Appendices A, B, and C for time histories, Bode plots, and transfer functions]

2.2 MODEL EQUATIONS OF MOTION, MODEL AERODYNAMICS, AND FLIGHT CONTROL SYSTEM PARAMETERS

2.2.1 Model Equations of Motion

The equations of motion programmed into the TIFS digital computer were:

Force Equations (in degrees)

1. $$\dot{V}_M = \frac{-\bar{q}\,S}{m}(C_D \cos\beta_M - C_y \sin\beta_M) - g\sin\gamma_M + \frac{1}{m}\left[(T_x \cos\alpha_M + T_z \sin\alpha_M)\cos\beta_M\right]$$

where: $$\sin\gamma_M = \cos\beta_M(\cos\alpha_M \sin\theta - \sin\alpha_M \cos\theta\cos\phi) - \sin\beta_M \cos\theta\sin\phi$$

2. $$\dot{\alpha}_M = \frac{-57.3\,\bar{q}\,S\,C_L}{m\,V_M\cos\beta_M} + \frac{57.3\,g}{V_M\cos\beta_M}(\cos\theta_M\cos\phi_M\cos\alpha_M + \sin\theta_M\sin\alpha_M) + q_M - \tan\beta_M(p_M\cos\alpha_M + r_M\sin\alpha_M) + \frac{57.3}{m\,V_M\cos\beta_M}(T_z\cos\alpha_M - T_x\sin\alpha_M)$$

3. $$\dot{\beta}_M = \frac{57.3\,\bar{q}\,S}{m\,V_M}(C_y\cos\beta_M + C_D\sin\beta_M) + \frac{57.3\,g}{V_M}\left[\cos\theta_M\cos\beta_M\sin\phi_M - \sin\beta_M(\cos\theta_M\cos\phi_M\sin\alpha_M - \sin\theta_M\cos\alpha_M)\right] + p_M\sin\alpha_M - r_M\cos\alpha_M - \frac{57.3}{m\,V_M}\left[\sin\beta_M(T_z\sin\alpha_M + T_x\cos\alpha_M)\right]$$

Moment Equations (body axis)

4. $$\dot{q}_M = \frac{57.3\ \bar{q}\ S\ \bar{c}}{I_{yy}} \left[C_m - \frac{\Delta x_{CG}}{\bar{c}} (C_L \cos \alpha_M + C_D \sin \alpha_M) + \frac{\Delta z_{CG}}{\bar{c}} (C_D \cos \alpha_M - C_L \sin \alpha_M) \right] + \frac{I_{zz}-I_{xx}}{I_{yy}} \frac{p_M r_M}{57.3} + \frac{I_{xz}}{I_{yy}} \frac{r_M^2 - p_M^2}{57.3} + \frac{57.3}{I_{yy}} (Z_T T_x - X_T T_z)$$

5. $$\dot{p}_M = L' + \frac{q_M r_M}{57.3} \frac{I_{yy}-I_{zz}}{I_{xx}} + \frac{p_M q_M}{57.3} \frac{I_{xz}}{I_{xx}} \left[1 + \frac{I_{xx}-I_{yy}}{I_{zz}} \right] + \frac{I_{xz}}{I_{xx}} N'$$

6. $$\dot{r}_M = N' + \frac{p_M q_M}{57.3} \frac{I_{xx}-I_{yy}}{I_{zz}} + \frac{q_M r_M}{57.3} \frac{I_{xz}}{I_{zz}} \left[-1 + \frac{I_{yy}-I_{zz}}{I_{xx}} \right] + \frac{I_{xz}}{I_{zz}} L'$$

7. $$L' = \frac{57.3\ \bar{q}\ Sb}{I_{xx}} \quad C_\ell + \frac{\Delta z_{CG}}{b} C_y \quad + \frac{y_T \Delta T_z}{I_{xx}} (57.3)$$

8. $$N' = \frac{57.3\ \bar{q}\ Sb}{I_{zz}} \quad C_n - \frac{\Delta x_{CG}}{b} C_y \quad - \frac{y_T \Delta T_x}{I_{zz}} (57.3)$$

9. $$\dot{h}_M = V_M \sin \gamma_M$$

10. $T_x = (F_L - F_R) \cos \alpha_T$

11. $T_z = -(F_L + F_R) \sin \alpha_T$

12. $\Delta T_x = (F_R - F_L) \cos \alpha_T$

13. $\Delta T_z = (F_L - F_R) \sin \alpha_T$

Nondimensional aerodynamic co-efficients were defined by the following equations:

a. $$C_D = C_{D_o} + C_{D_\alpha}(\alpha) + C_{D_{\alpha^2}}(\alpha^2) + C_{D_{\delta_e}}(\delta_e)$$
$$+ C_{D_{LG}}(LG) + C_{D_{GE}} F_D(h)$$

b. $$C_L = C_{L_o} + C_{L_\alpha}(\alpha) + \frac{\bar{c}}{2V}(C_{L_{\dot{\alpha}}}\dot{\alpha} + C_{L_q} q)$$
$$+ C_{L_{\delta_e}} \delta e + C_{L_{SP}} SP + C_{L_{\delta H}} \delta H$$
$$+ C_{L_{\delta_{CN}}} \cdot \delta_{CN} + C_{L_{GE}} F_L(h)$$

c. $$C_m = C_{m_o} + C_{m_\alpha}(\alpha) + \frac{\bar{c}}{2V}(C_{m_{\dot{\alpha}}}\dot{\alpha} + C_{m_q} q)$$
$$+ C_{m_{\delta_e}} \delta_e + C_{m_{\delta H}} \delta H + C_{m_{\delta_{LG}}} \delta_{LG} + C_{m_{GE}} F_m(h)$$

d. $C_n = C_{n_\beta}\beta + C_{n_{\delta_r}}\delta_r + \frac{b}{2V}(C_{n_p}p + C_{n_r}r)$

$+ C_{n_{\delta_a}}\delta_a + C_{n_{\delta_{SP}}}\delta_{SP}$

e. $C_\ell = \frac{b}{2V}(C_{\ell_p}p + C_{\ell_r}r) + C_{\ell_\beta}\beta + C_{\ell_{\delta_a}}\delta a$

$+ C_{\ell_{\delta_r}}\delta_r + C_{\ell_{F_{in}}}\delta_{F_{in}} + C_{\ell_{F_{out}}}\delta_{F_{out}} + C_{\ell_{\delta_{CN}}}\delta_{CN}$

f. $C_y = C_{y_\beta}\beta + C_{y_{\delta_r}}\delta_r + C_{y_{\delta_{CN}}}\delta_{CN}$

$+ \frac{b}{2V}(C_{y_p}p + C_{y_r}r)$

where: δ_{SP} = Spoilers

δ_{CN} = Canards

δ_H = Horizontal Tail

$\delta_{F_{in}}$ = Flaps Inboard

$\delta_{F_{out}}$ = Flaps Outboard

2.2.2 Model Aerodynamics

It was desired that the "Generic Transport" be typical of future medium sized relaxed stability transport aircraft. It should be around 200,000 lbs. gross weight and should have Level 1 lateral/directional characteristics for this longitudinal investigation. Consideration was given to options such as: the NLR F-4 configuration (Reference 3), various configurations from the Large Aircraft program (Reference 4), and Shuttle Orbiter configurations. As this search for a "Generic Transport" was being conducted the NASA Twin Body program was being modeled in TIFS. A look at this program confirmed that the Twin Body Model could meet the requirements for the

"Generic Transport" with minor modifications. The gross weight was 193,000 lbs., the augmented lateral/directional characteristics were Level 1, it could be destabilized by changing C_{m_α}, various values of $1/\tau_{\theta_2}$ could be obtained by changing C_{L_α}, and by changing $C_{L_{\delta_e}}$ "shuttle like" configurations were available. Consequently it was determined that a suitable "Generic Transport" could be obtained in a very cost effective and efficient manner by modifying the twin body data base and placing the pilot on centerline. As C_{m_α} and C_{L_α} are not independent variables the list of derivatives that required change in order to obtain the desired modification grew to:

$$C_{L_0},\ C_{L_\alpha},\ C_{L_{\delta_e}},\ C_{D_0},\ C_{D_\alpha},\ C_{D_{\alpha^2}},\ C_{D_{C_{L_0}}},\ C_{D_{C_L}},\ C_{D_{C_L^2}},\ C_{m_0} \text{ and } C_{m_\alpha}.$$

The additional derivatives requiring change resulted from the necessity to maintain trim conditions and drag front-side/back-side relationships as C_{L_α} and C_{m_α} were varied. A more detailed account is given below.

2.2.2.1 Static Stability Considerations

Study of Reference 2, 3, and 4 and various shuttle orbiter literature indicated that a unstable value of $\lambda_1 = +0.3$ would be a "typical worst case" value for an unaugmented relaxed stability transport. Consequently a three-degree-of-freedom computer program was used to determine that a value of $C_{m_\alpha} = +0.02269$ (per deg), 1.3 (per rad) would provide a nominal value of $\lambda_1 = +0.3$ as $1/\tau_{\theta_2}$ was varied from 0.72 to 1.0:

C_{m_α} (1/deg)	0.02269	0.02269	0.02269
$1/\tau_{\theta_2}$	0.38	0.72	1.0
λ_1	0.346	0.236	0.221
T_{double}	2.0 sec	2.9 sec	3.1 sec

It was necessary to maintain trim C_m as C_{m_α} was changed to accomplish the required instability. The basic Twin Body data for C_m was of the form:

$$C_m = C_{m_{Basic}} + C_{m_{\delta_e}}(\delta_e) + C_{m_{\delta_h}}\delta_h + C_{m_{LG}}LG$$
$$+ C_{m_{\dot\alpha}}\dot\alpha + C_{m_q}q + C_{m_{GE}}GE$$

$C_{m_{Basic}}$ was a table look up of $C_{m_{Basic}}$ vs α. $C_{m_{Basic}}$ was put in the form:

$$C_{m_{Basic}} = C_{m_0} + C_{m_\alpha}\alpha$$

where C_{m_α} was determined as previously discussed and C_{m_0} was determined from trim conditions. Consequently the $C_{m_{Basic}}$ table was replaced with:

$$C_{m_{Basic}} = -0.5018 + (0.02269)\alpha$$

The overall C_m equation was then in the final form:

$$C_m = C_{m_0} + C_{m_\alpha}\alpha + C_{m_{\delta_e}}\delta_e + - - - -$$

For the neutral static stability configuration (3-1-3 and 3-2-4) C_{m_α} was set to zero and C_{m_0} was set to $C_{m_{Basic_{Trim}}}$.

2.2.2.2 Lift Curve Slope Considerations

It was desired to make $1/\tau_{\theta_2}$ one of the experiment variables. This was effected by changing C_{L_α} to obtain values of $1/\tau_{\theta_2}$ of 0.38, 0.72, and 1.0. From the lift and moment equations and the resultant $q(s)/\delta_e$ transfer function it can be shown that:

$$\frac{1}{\tau_{\theta_2}} \simeq \frac{L_\alpha - M_\alpha \dfrac{L_{\delta_e}}{M_{\delta_e}}}{1 + \dfrac{M_{\dot{\alpha}}}{M_{\delta_e}}}$$

and as a first approximation:

$$\frac{1}{\tau_{\theta_2}} \approx L_\alpha = \frac{g}{V}\frac{C_{L_\alpha}}{C_L}$$

This last relationship was used as the start of an iterative process using the three degree of freedom computer program to arrive at the final values of C_{L_α} for the desired levels of $1/\tau_{\theta_2}$ with the following results:

$1/\tau_{\theta_2}$	0.38	0.72	1.0
C_{L_α} (1/deg)	0.00632	0.1222	0.1745
C_{L_α} (1/rad)	0.36	7.0	10.0

2.2.2.3 Lift Curve Considerations

In order to maintain trim conditions with changes in C_{L_α} a new value of C_{L_0} was calculated for each value of C_{L_α}:

$$C_{L_{Trim}} = C^n_{L_0} + C^n_{L_\alpha}(\alpha_{Trim})$$

$$\therefore \quad C^n_{L_0} = C_{L_{Trim}} - C^n_{L_\alpha}(\alpha_{Trim})$$

(where n denotes a specific value of C_{L_α})

consequently the final C_L relationship was:

$$C_L = C^n_{L_0} + C^n_{L_\alpha}(\alpha)$$

where:

C_{m_α} = 0.02269 case

$1/\tau_{\theta_2}$	0.38	0.72	1.0
C_{L_α}	0.06632	0.1222	0.1245
C_{L_0}	1.310	1.136	0.973

For the C_{m_α} = 0 case new values of C_{L_α} were required for the $1/\tau_{\theta_2}$ values desired. These were obtained in the same manner as previously described and new values of C_{L_0} were subsequently calculated.

C_{m_α} = 0 case

$1/\tau_{\theta_2}$	0.38	0.72	1.0
C_{L_α}	0.07155	0.1274	0.1815
C_{L_0}	1.294	1.120	0.9507

2.2.2.4 Drag Polar Considerations

It was desired to maintain the trim condition at the "front side" of the drag polars. In order to achieve this it was necessary that $C_{L_{Trim}}$, $C_{D_{Trim}}$ and the C_D/C_L relationship be maintained as C_{L_α} was varied.

The drag polar of the Twin Body was in table look up form of C_D vs α. By iterative and graphical techniques this was converted to the form:

$$C_{D_{Basic}} = C_{D_0} + C_{D_\alpha}\alpha + C_{D_{\alpha^2}}\alpha^2$$

$$C_{D_{Basic}} = 0.1755 + 0.0142\ \alpha + 0.001\ \alpha^2$$

consequently the C_D relationship became:

$$C_D = C_{D_{Basic}} + C_{D_{\delta_e}}\delta_e + C_{D_{LG}}LG + C_{D_{GE}}GE$$

In order to maintain the C_d/C_L relationship it was necessary to put the $C_{D_{Basic}}$ equation in terms of C_L:

$$C_L = C^n_{L_0} + C^n_{L_\alpha}(\alpha)$$

$$\therefore \alpha = \frac{C_L - C^n_{L_0}}{C^n_{L_\alpha}}$$

$\therefore$ by substitution into:

$$C_{D_{Basic}} = C_{D_0} + C_{D_\alpha}\alpha + C_{D_{\alpha^2}}\alpha^2$$

the equation in terms of C_L becomes:

$$1. \qquad C_D = \left[C^n_{D_0} - \frac{C^n_{D_\alpha} C^n_{L_0}}{C^n_{L_\alpha}} + \frac{C^n_{D_{\alpha^2}} (C^n_{L_0})^2}{(C^n_{L_\alpha})^2} \right]$$

$$+ \left[\frac{C^n_{D_\alpha}}{C^n_{L_\alpha}} - 2\,\frac{C^n_{D_{\alpha^2}} C^n_{L_0}}{(C^n_{L_\alpha})^2} \right] C_L$$

$$+ \left[\frac{C^n_{D_{\alpha^2}}}{(C^n_{L_\alpha})^2} \right] C_L^2$$

$$= \left[C_{D_{C_{L_0}}} \right] + \left[C_{D_{C_L}} \right] \cdot C_L + \left[C_{D_{C_L^2}} \right] C_L^2$$

inserting trim values of C_{L_0} and C_{L_α}, C_{D_0}, C_{D_α} and $C_{D_{\alpha^2}}$ yields:

$$2. \qquad C_D = (0.1358) + (-0.05336)C_L + (0.0764)C_L{}^2$$

In order to maintain the trim C_D vs C_L relationship the values of $C_{D_{C_{L_0}}}$, $C_{D_{C_L}}$, and $C_{D_{C_L^2}}$ must remain constant as C_{L_α} is changed.

By setting $C_{D_{C_{L_0}}}$, $C_{D_{C_L}}$ and $C_{D_{C_L^2}}$ of equation 1 equal to the trim values for $C_{D_{C_{L_0}}}$, $C_{D_{C_L}}$, and $C_{D_{C_L^2}}$ of equation 2, values for $C_{D_{\alpha_0}}$, C_{D_α}, and $C_{D_{\alpha^2}}$ can be found for each value of C_{L_α} that will maintain the desired "front side" relationship.

This procedure results in:

3. $$C^n_{D_{\alpha^2}} = (0.0764)(C_{L_\alpha})^2$$

4. $$C^n_{D_\alpha} = (-0.05336)(C^n_{L_\alpha}) + 2C^n_{D_{\alpha^2}}\left(\frac{C^n_{L_0}}{C^n_{L_\alpha}}\right)$$

5. $$C_{D_0} = 0.1358 + C^n_{D_\alpha}\left(\frac{C^n_{L_0}}{C^n_{L_\alpha}}\right) - C^n_{D_{\alpha^2}}\frac{(C^n_{L_0})^2}{(C^n_{L_\alpha})^2}$$

Using equations 3, 4, and 5 the following table was obtained:

$C_{m_\alpha} \neq 0$ case

$1/\tau_{\theta 2}$	0.38	0.72	1.0
C_{D_0}	0.1970	0.1737	0.208
C_{D_α}	0.00974	0.01467	0.01663
$C_{D_{\alpha^2}}$	0.000336	0.00114	0.00233

$C_{m_\alpha} = 0$ case

$1/\tau_{\theta 2}$	0.38	0.72
C_{D_0}	0.1906	0.1720
C_{D_α}	0.01099	0.0150
$C_{D_{\alpha^2}}$	0.000471	0.00124

2.2.2.5 Pitch Rotation Point Considerations

The subject flight program required models of three different pitch rotation locations i.e., center of percussion. First was the Generic Transport with the rotation point conventionally located a nominal distance behind the pilot. Second, a "shuttle orbiter like" configuration with the rotation point in front of the pilot. Third, a canard "shuttle like" configuration with the rotation point located a considerable distance behind the pilot.

Figure 3 shows the geometric locations used in the investigation. The locations (ℓ_r = distance from the CG) were obtained by changing $C_{L_{\delta_e}}$ in the following manner:

From Appendix G:

$$\ell_r = \frac{Z_{\delta_e}}{M_{\delta_e} + Z_{\delta_e} M_{\dot{w}}}$$

where:

$$Z_{\delta_e} = -\frac{1}{m} \bar{q} \, S \, C_{L_{\delta_e}}$$

$$M_{\delta_e} = \frac{1}{I_y} \bar{q} \, S \, \bar{c} \, C_{m_{\delta_e}}$$

$$M_{\dot{w}} = \frac{\rho \, S \, \bar{c}^2}{4 \, I_y} C_{m_{\dot{\alpha}}}$$

Using these relationships the following values were obtained:

	Shuttle	Generic Transport	Canard SSV
ℓ_r	+44 ft	+20 ft	-20 ft
$C_{L_{\delta_e}}$	0.03239	0.0149	-0.0149

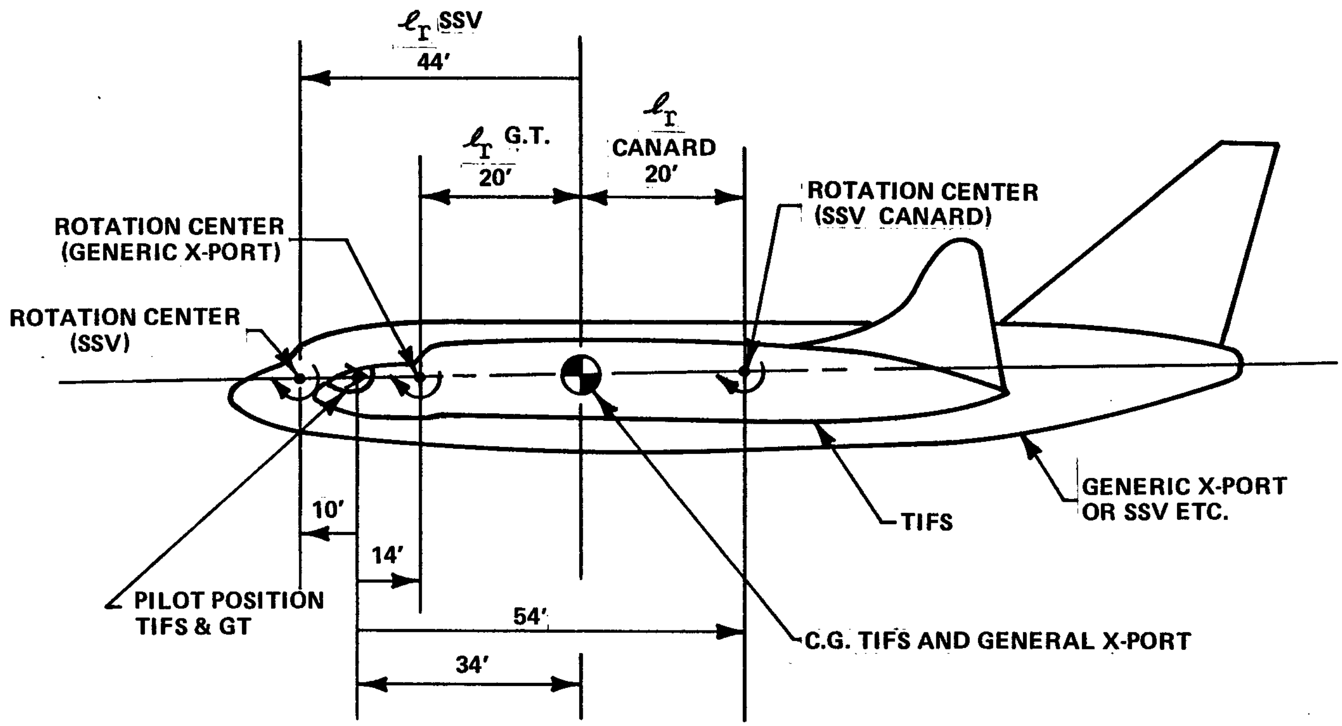


Figure 3 SIMULATION GEOMETRY

2.2.2.6 Thrust Considerations

The symmetric thrust acted 0.5 ft below model CG and was commanded by a four handled throttle lever. The Twin Body thrust model was found to be somewhat complex and consequently the thrust model was changed to a simple first order response with a one second time constant. This proved to be an excellent thrust response and the thrust control task became transparent to the overall pitch tasks.

2.2.2.7 Time Delay Considerations (Pitch Axis)

It was desired to match inflight time delays with those of the ground computer generated time histories of Appendix A (10 sec time histories) and Appendix H (1 sec time histories).

Measurements from Appendix H showed the dynamic element time delay (effective time delay using maximum slope intercept) of all configurations was of the order of 115 milliseconds. This was made up of:

Form Assumed During Experimental Design	Effective Time Delays
Second Order Model Actuator	$\omega_n = 30 \simeq 46$ ms
	$\zeta = 0.7$
Second Order Feel System	$\omega_n = 20 \simeq 70$ ms
	$\zeta = 0.7$
	116 ms

In the TIFS aircraft the model actuator was a third order actuator (twin body) and the feel system was the TIFS feel system of $\omega_n = 25$, $\zeta = 0.7$. Measurements from flight data showed an effective time delay from stick force to model motion of approximately 100 ms (with the exception of Shuttle configuration 8-5-5 which was 175 ms). Additionally, TIFS model following delay from model motion to TIFS motion was 93 ms for a total time delay of 193 ms from stick force to TIFS motion. Model following delay could have been reduced through additional flight tests, however, a more cost effective way to reduce overall time delay was to remove the third order actuator from the model. This reduced the time delay from stick position to model motion to 24 ms.

The time delay account became:

TIFS Feel System (0.7, 25)	=	56 ms
Generic Transport Model	=	24 ms
TIFS Model Following	=	93 ms
	Total	173 ms

Considering that the minimum effective time delay that can be expected from an aircraft with an actuator and a feel system will be 100 ms from these dynamic elements alone it was felt that the 173 ms figure was probably representative of practical designs and did not justify expenditure of time and money in attempts to reduce it. Subsequent flight results showed a number of Level 1 configurations thus demonstrating that the decision to accept the 173 ms time delay (stick force to TIFS motion) for this investigation was reasonable.

Some shuttle like configurations required additional time delay and these were accomodated using the command path transport time delay circuit of the flight control system (Figure 1). Shuttle configuration time delays are shown below:

Config.	Desired Delay	TIFS Fixed Delay	Added Transport Delay	Total Delay Flown
8-1-5	150 ms	173 ms	0	173 ms
8-2-5	170 ms	173 ms	0	173 ms
8-3-5	220 ms	173 ms	47 ms	220 ms
8-4-6	150 ms	173 ms	0	173 ms
8-5-5	208 ms	173 ms	35 ms	208 ms

2.2.2.8 Feel System Parameters

The feel system parameters were chosen during the calibration flights. Known good feel system parameters were used as the starting point and were slightly modified to provide good characteristics. Ideally the feel system should have been "transparent" to the flight test. The lack of evaluation pilot comments concerning the feel system (Appendix F) indicates that this was achieved.

Below are the feel system parameters that resulted from the calibration flights and were used throughout the investigation:

	Column Pitch	Wheel Roll	Pedals Yaw
Gradient	12 (lbs/in)	0.27 (lb/deg)	36 (lb/in)
ω_n (rad/sec)	25	20	12
ζ	0.7	1.5	0.6
Breakout (lbs)	4.0	1.0	12

2.2.3 Generic Transport Physical Characteristics

Constant Characteristics

Weight (W) = 193,000 lbs.

Mass (M) = 5999.4 slugs

Wing Aera (S) = 2147 ft^2

Wing Span (b) = 157 ft

Wing Chord (c) = 15.074 ft

I_{xx} = 4,003,900 slug-ft^3

I_{yy} = 5,408,550 slug-ft^3

I_{zz} = 9,181,470 slug-ft^3

I_{xz} = 223,410 slug-ft^3

$X_{Pilot\ Eye}$ = 34 ft

T_z = +0.5 ft

Trim Conditions

V_{Trim} = 132 KIAS (223 fps)

q = 59.14 psf

α_T = 3.12 deg

δ_{Flap} = 50 deg

$\delta_{h_{Trim}}$ = -8.83 deg

$\delta_{e_{Trim}}$ = 0

T_{Trim} = 30,620 lbs.

C_{L_T} = 1.51

C_{D_T} = 0.244

Longitudinal Non-Dimensional Derivatives (degrees)

		Shuttle	Generic Transport	Canard
	$1/\tau_{\theta_2}$ =	0.38	0.72	1.0
$M_\alpha \neq 0$	C_{L_0}	1.310	1.136	0.973
	C_{L_α}	0.06632	0.1222	0.1745
$M_\alpha = 0$	C_{L_0}	1.294	1.120	0.9507
	C_{L_α}	0.07155	0.1274	0.1815

	Shuttle	Generic Transport	Canard
$C_{L_{\delta_e}}$	0.03239	0.0149	-0.0149
$C_{L_{GE}}$	0.0920 F(h)		

	$1/\tau_{\theta_2}$ =	0.38	0.72	1.0
$M_\alpha \neq 0$	C_{D_0}	0.1970	0.1737	0.208
	C_{D_α}	0.00974	0.01467	0.01663
	$C_{D_{\alpha^2}}$	0.000336	0.00114	0.00233
$M_\alpha = 0$	C_{D_0}	0.1906	0.1720	-
	C_{D_α}	0.0110	0.0150	-
	$C_{D_{\alpha^2}}$	0.000471	0.00124	

$C_{D_{\delta_e}}$	0.00005
$C_{D_{LG}}$	0.01493
$C_{D_{GE}}$	-0.0928 F(h)
C_{m_0}	-0.5018 (-0.431, $M_\alpha = 0$)
C_{m_α}	0.02269 (0 , $M_\alpha = 0$)
$C_{m_{\delta_e}}$	-0.0443
$C_{m_{\delta_H}}$	-0.0642
$C_{m_{LG}}$	-0.0087
$C_{m_{GE}}$	-0.0072 F(h)
$C_{m_{\dot\alpha}}$	-0.1352
C_{m_q}	-0.5848

Lateral/Directional Non-Dimensional Derivatives (degrees)

C_{y_β}	-0.03136
C_{y_p}	0.00563
C_{y_r}	0.01345
$C_{y_{\delta_r}}$	0.00536
C_{ℓ_β}	-0.00256
C_{ℓ_p}	-0.01022
C_{ℓ_r}	0.00749
$C_{L_{\delta_a}}$	0.00148
$C_{\ell_{\delta_{SP}}}$	0.00023
$C_{\ell_{\delta_r}}$	0.00050
C_{n_β}	0.00394
C_{n_p}	-0.00074
C_{n_r}	-0.00552
$C_{n_{\delta_a}}$	0.00023
$C_{n_{\delta_{SP}}}$	0.00024
$C_{n_{\delta_r}}$	-0.00169

Lateral/Directional Characteristics

The lateral/directional characteristics were not varied during the investigation and were found to be Level 1 and consequently "transparent" to the longitudinal investigation.

Dutch Roll Mode

ω_n (rad/sec)	0.768
ζ	0.297
$\zeta\omega_n$ (rad/sec)	0.228
P (sec)	8.57
ϕ/β	0.188

Roll Spiral Mode	
T_r (sec)	-
t_{s^2} (sec)	-
ω_{rs} (rad/sec)	4.741
ζ_{rs}	0.369
$\zeta_{rs}\,\omega_{rs}$ (rad/sec)	1.748
P_{rs} (sec)	1.47

Roll Control Parameters	
ω_ϕ/ω_d	1.000
ζ_ϕ/ζ_d	1.001

Ground Effect

The ground effect model was that of the NASA Twin Body program and was defined as below:

$$C_{L_{GE}} = 0.0920\ F(h)_{C_L, C_m}$$

$$C_{D_{GE}} = -0.0928\ F(h)_{C_D}$$

$$C_{m_{GE}} = -0.0072\ F(h)_{C_L, C_m}$$

where:

h_{WH}(ft)	$F(h)_{C_L, C_m}$	$F(h)_{C_D}$
≥ 157	0	0
130	0.002	0.011
110	0.006	0.033
90	0.013	0.070
80	0.021	0.097
70	0.034	0.131
60	0.054	0.174
50	0.085	0.227
40	0.128	0.294
30	0.188	0.391
20	0.275	0.519
10	0.435	0.714
0	1.000	1.000

2.2.4 Flight Control System Parameters

Figure 1 is the pitch axis flight control system used in this investigation. The lateral/directional flight control system was that of the NASA Twin Body aircraft with the pilot located on the centerline. The lateral/ directional flight control system, as implemented, proved to be Level 1 for the tasks flown and was not a variable or a factor in this pitch axis investigation.

The pitch axis flight control system was implemented in analog form. It provided the various flight control options required for the flight program:

Variable Parameters	Description	Utilization
K_C	Command gain	To adjust pitch sensitivity.
T_1	Transport Time Delay	Provide proper overall time delay for the various configurations.
T_{WO}	Washout	Provide monotonic stick forces in the landing flare.
T_Z, T_F	Prefilter	Provide manipulation of roots to restore $1/\tau_{\theta 2}$ or match various shuttle configurations.
K_L	Loop Gain	Provide desired pole configurations.
K_q	Pitch Rate Feedback Gain	Provide desired pole configurations, few cases.
K_I	Integrator Gain	Provide desired control system zero configurations.
K_α	α Feedback Gain	Provide "normal" aircraft configuration.
$\Delta\alpha$	α limiter	Not used.
α_{BIAS}	α bias	Not used.
$\frac{g}{V}\phi^2$	Turn coordination	Provide elevator for turns.

2.2.4.1 Development of Flight Control Parameters

The development of the flight control parameters for the 27 configurations tested was the result of a process of iteration using two Calspan Stability and Control computer programs:

1. A Calspan three-degree-of-freedom program was supplied with aircraft model parameters. This program then provided model roots and model transfer functions for the seven models used in the investigation.

2. The roots of step 1 were combined with various flight control parameters in the Calspan "N" degree-of-freedom program that produced configuration transfer functions (Appendix C), root locus plots (Appendix I), Bode plots (Appendix B), and time histories (Appendix A).

Root locus plots were obtained with iterations of C_{L_α}, K_I, K_L, C_{m_α}, K_q, and K_α. From those plots, sets of parameters were chosen to provide the desired pole/zero locations for the various configurations. These parameter sets were fed to the Calspan "N" degree-of-freedom program along with the proper aerodynamic model parameters to provide transfer functions, Bode plots, and time histories for the 27 tested configurations.

These combined parameter sets were used to develop the configuration table of Appendix D. This configuration table was the reference for configuration set up in the TIFS aircraft.

Section 3
EXPERIMENT MECHANIZATION AND PROCEDURES

3.1 EQUIPMENT

The USAF Total In-Flight Simulator (TIFS) was used as the test vehicle in this experiment. TIFS is a highly modified C-131 (Convair 580) configured as a six-degree-of-freedom simulator (Figure 4). It has a separate evaluation cockpit forward and below the normal C-131 cockpit. When flown from the evaluation cockpit in the simulation or fly-by-wire mode, the pilot control commands are fed as inputs to the model computer which calculates the aircraft response to be reproduced. These responses, along with TIFS motion sensor signals, are used to generate feedforward and response error signals, which drive the six controllers on the TIFS (Figure 5). The model-following system gains are documented in Appendix L. The result is a high fidelity reproduction of the motion and visual cues at the pilot position of the model aircraft. More detailed descriptions of the TIFS can be found in References 1, 2, 3 and 4.

This experiment made use of the following major features inherent in the TIFS aircraft:

1. Independent control of all six forces and moments by use of elevator, aileron, rudder, throttle, direct lift flaps and side force surfaces.

2. Longitudinal and lateral/directional model-following systems to provide the evaluation pilot with motion and visual cues representative of the simulated aircaft.

3. Separate evaluation cockpit capable of accepting appropriate pilot controls, displays, and co-pilot assistance. (An observer, but never co-pilot, was present there).

4. Evaluation cockpit instruments included standard IFR instrument displays featuring an ADI and an HSI as the

primary instruments, with angle of attack displayed on an indicator on the right hand side of the HSI and sideslip displayed on the indicator above the HSI. The vertical and horizontal bars on the ADI displayed command information for tracking localizer and glide slope, respectively.

5. Digital magnetic tape recording system to record control inputs and appropriate aircraft responses.

6. Two cassette tape voice recorders for recording evaluation pilot comments, and TIFS crew comments.

7. The capability to simulate artificial or cancel actual crosswinds up to 15 kts incorporated in the model-following system.

8. Turbulence simulated by playing pre-recorded random signals into the model through filters mechanized to produce the proper power spectrum of turbulence (natural turbulence was measured and added to these signals to improve the model-following when rough air was experienced).

9. A signal light located above the ADI and audio signal to indicate simulated touchdown of main landing gear. (Used only during calibration flights for work up to full touchdowns).

10. Adjustable transport time delay circuits, available to simulate time delay in the pilot's commands the elevator and aileron controls.

11. Digital computing equipment recently installed in the TIFS airplane, to calculate model aerodynamics and evaluate kinematic equations.

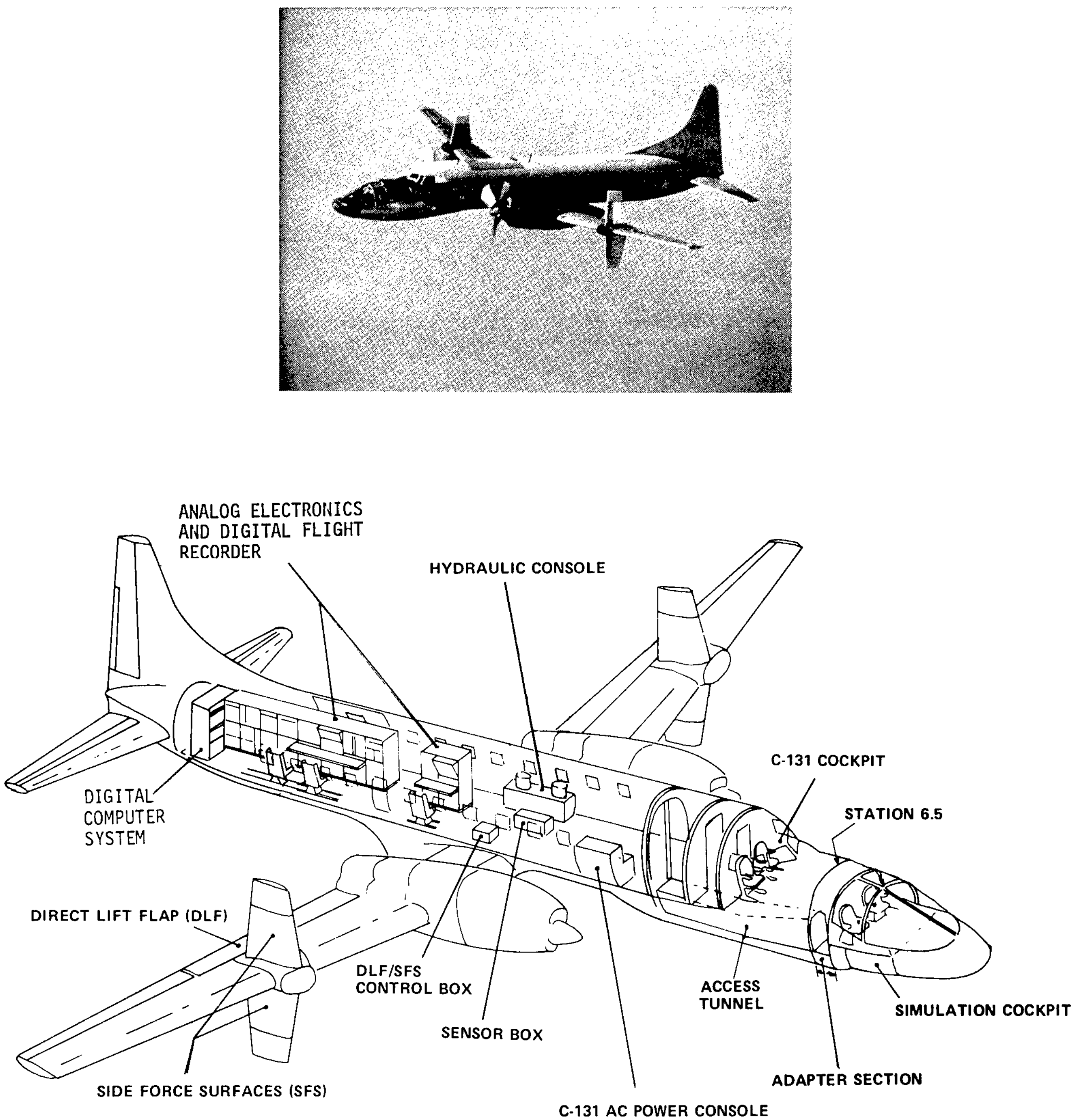


Figure 4 USAF TOTAL IN-FLIGHT SIMULATOR (TIFS)

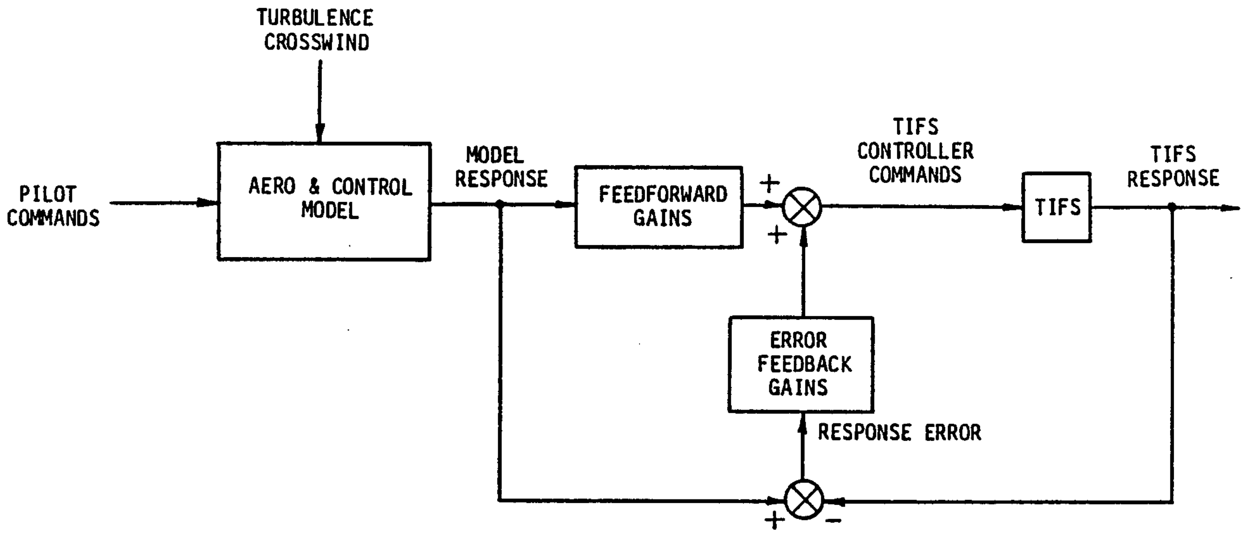


Figure 5 TIFS MODEL FOLLOWING SIMULATION

3.2 SIMULATION GEOMETRY

The TIFS motion was configured to reproduce model motion at the evaluation pilot's eye point as if the TIFS were positioned as shown in Figure 3. As this was a generic rather than specific simulation it was chosen to superimpose TIFS c.g. and Generic Transport c.g. Additionally, the cockpits of the two aircraft were superimposed. Consequently, no transformations were required from TIFS c.g. to model c.g.

Approaches were made to touchdown and TIFS wheels and Generic Transport wheels were superimposed. This simplified geometry negated the requirement for eye position and wheel height transformations.

3.3 EVALUATION COCKPIT CONFIGURATION

The evaluation cockpit was configured as illustrated in Figure 6. The controls were standard wheel and rudders. Thrust was controlled by four throttle levers tied together and total thrust was indicated on a single gage. Asymmetric thrust control was not provided.

The evaluation pilot's instrument panel is shown in Figure 7. It was a standard configuration with flight director or raw data information available on the VSI.

TIFS evaluation cockpit is a dual pilot side by side arrangement. For this investigation the right seat was occupied by a NASA flight test engineer. The engineer observed all approaches and landings, assisted in conduct of the flight test card, recorded touchdown dispersion, and recorded summaries of evaluation pilot comments and handling qualities ratings (HQR) to provide timely post flight analysis. (This flight data became Appendix E).

3.4 EVALUATION TASK AND PROCEDURES

The subject aircraft in these evaluations was a 193,000 lb. gross weight, Generic Transport in the final approach, flare, and touchdown phases.

The evaluation pilot was given control of the aircraft on the down wind leg and performed a visual turning approach to a 1.5 to 2 mile final

Figure 6 TIFS EVALUATION COCKPIT

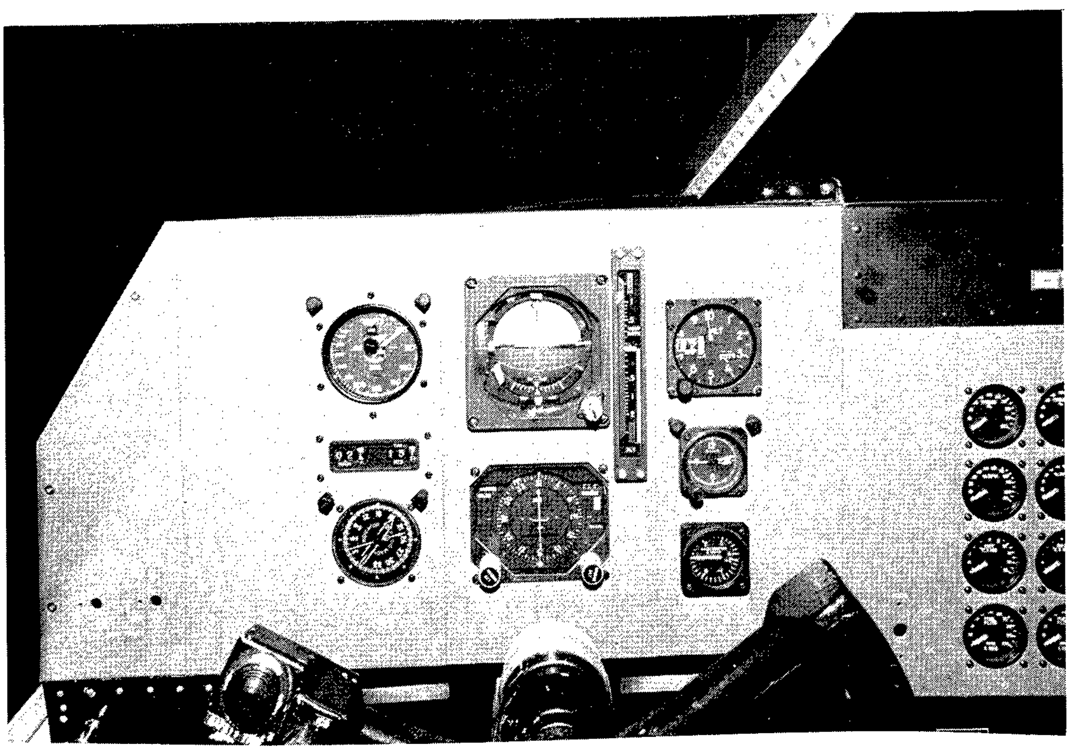


Figure 7 CAPTAIN'S INSTRUMENT PANEL IN EVALUATION COCKPIT

approach. The ILS glide slope was intercepted in the turn and was held to a point 3500 ft. from the runway/glide slope intercept point. A constant speed of 132 KIAS was held throughout the approach until landing flare.

Figure 8 details the final approach and flare geometry. A final approach "barrier" was defined as projecting up from the ground at a point 3500 ft. short of the runway and glide slope intercept point and up to the ILS glide path. The evaluation pilot was not allowed to descend below the ILS glide slope until passing the "barrier" (the position 3500 ft. short of the runway/glide slope intercept was well marked by a railroad track). Peer pressure from the safety pilots and the flight test engineer was found to be quite sufficient to prevent barrier duck under.

In addition to the altitude constraint of the barrier, lateral off sets of 300 ft. (either left or right, and obtained visually by lining up on runway markers) were used to provide secondary tasking thus preventing pre-occupation with the pitch task. In order to further assure pitch task activity a $(1 - \cos \omega t)$ angle of attack gust was fed to the model in the zone depicted in Figure 8. The magnitude of this disturbance was varied as a function of C_{L_α} to cause a "standard" flight path disturbance.

The "desired" touchdown area was defined as being 500 ft. long and 20 ft. wide (±10 ft. of centerline) starting 250 ft. past the runway/glide slope intercept. The "Adequate" touchdown area was defined as 1000 ft. long, 40 ft. wide and starting at the same point on the runway. Airspeed requirements were: "Desired" 132 ±3 KIAS, "Adequate" 132 ±5 KIAS, both at barrier passage. "Desired" sink rate at touchdown was defined as 0 to 3 fps and "Adequate" as 3 to 6 fps (these values could be obtained from the data records, however, experience has shown that 0-3 fps touchdowns result in "smooth" landings, 3-6 fps touchdowns result in "solid" landings, and touchdowns in excess of 6 fps can be recognized by any crew member with a 95% confidence level).

Touchdown parameters were obtained by runway marks (for x distance), known tread distance of TIFS (for y distance), and as described above for sink rate. These parameters were taken by both safety pilots and the flight test engineer in the right evaluation seat. These combined with the evaluation pilots comments and ratings provided the evaluation data.

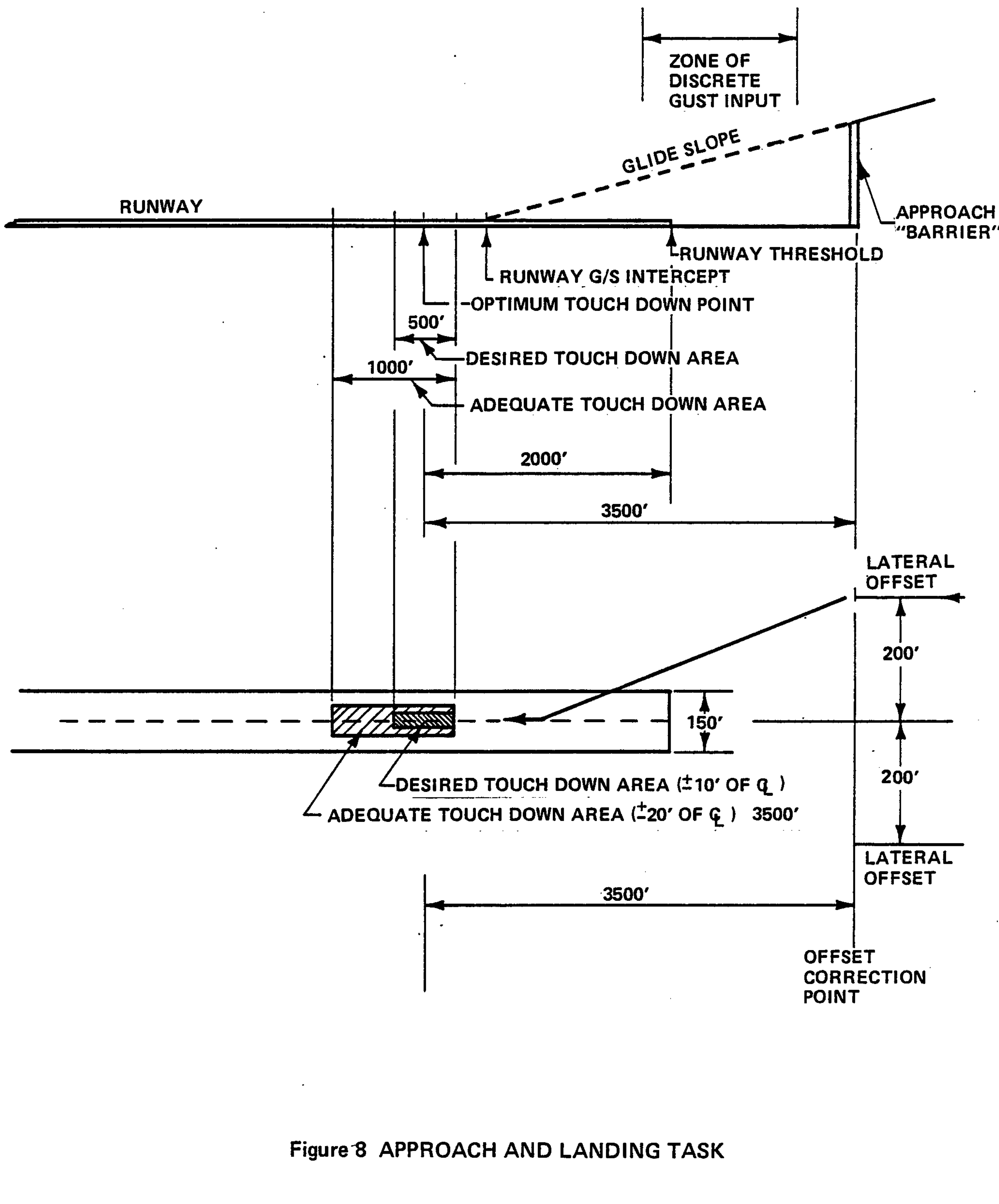


Figure 8 APPROACH AND LANDING TASK

The design goal of the above task was to achieve sufficient pilot gain in the pitch axis to provide an adequate spread in the Handling Qualities Ratings (HQR's) but not to be so difficult or easy so as to bias the HQR's one way or another. The bell curve of Figure 9 (HQR distribution) indicates that the task design goal was met.

3.5 EVALUATION SEQUENCE

The evaluation pilot was given control of the aircraft on the down-wind leg. At this time electronic test inputs were made in order to verify the configuration. The evaluation pilot would then conduct a visual turning approach to intercept the glide slope approximately two miles from touchdown. He would visually line up for the offset and continue down the glide slope. At the "barrier" position (3500 ft from touchdown) the correction for the off-set would commence and thrust and pitch would be adjusted for landing. At approximately 2000 ft. from touchdown a descrete ($1 - \cos \omega t$) angle of attack gust would be fed to the aircraft model to cause a standard flight path disturbance. The evaluation pilot would fly through the gust to flare and touchdown. At touchdown the safety pilots would take control of the aircraft (or at any time prior to touchdown if dictated by the situation). At this point the flight test engineer would record touchdown dispersion and the eva-luation pilot would begin his comments and give the HQR. This data was manually recorded by the flight test engineer as well as on voice tape (transcripts of voice tape comments are in Appendix F). The safety pilots would execute the climbout while the TIFS technical crew would set up the next configuration (if required) to repeat the process.

A normal evaluation consisted of two approaches, however, the evalu-ation pilot had the option of repeats if desired.

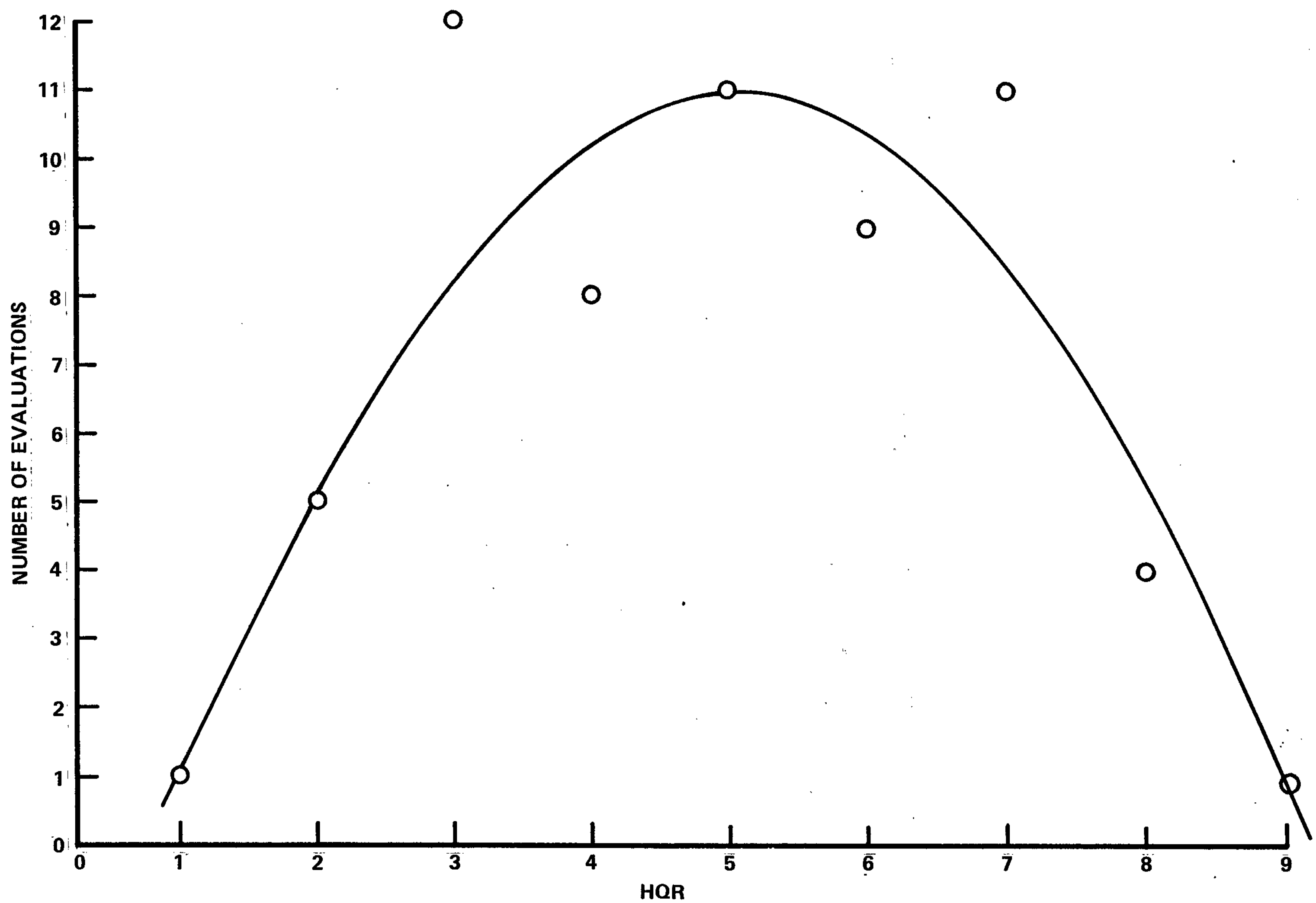


Figure 9 PITCH RATE INVESTIGATION HQR DISTRIBUTION

3.6 PILOTS AND EVALUATION SUMMARY

Three evaluation pilots participated in this flying qualities investigation. A Calspan pilot (also the project engineer) conducted the calibration flights which determined the accuracy of the simulations, the efficacy of the task, and the adequacy of the lateral/directional axis and thrust response for the flight program. Two NASA pilots (NASA Dryden and Langley) conducted the evaluations. Sixty one evaluations, and one hundred thirty four approaches were flown for twenty seven configurations. The NASA Dryden pilot conducted thirty four evaluations on twenty seven configurations and the NASA Langley pilot conducted twenty seven evaluations on twenty three configurations. The flight program is summarized below.

PITCH RATE CRITERIA FLIGHT SUMMARY

(1 September 1983 thru 23 September 1983)

	Dryden	Langley	Calspan	Total
Calibration Flights	-	-	4	4
Evaluation Flights	9	9	-	18
Evaluations	34	27	-	61
Approaches	70	64	-	134
Flight Hours	10.1	8.5	8.2	26.8

3.7 PILOT COMMENT CARD AND RATING SCALE

The evaluation pilots were briefed on the general experiment purpose and flight task details. They had knowledge of what the 27 configurations were but no knowledge of which of those configurations would be given on each flight.

Pilot technique is necessarily different for integrated pitch rate flight control systems than for "conventional" systems that require increasing average pull forces in the landing flare (i.e. monitonic). Consideration was given to informing the evaluation pilots, before hand, which type of control system they had. It was decided to proceed with a "blind" experiment in the initial stages. As a result of the first set of data the decision was made to continue with the blind experiment. The pilots adapted to technique changes rapidly and in some cases were unaware of using different techniques.

An evaluation normally consisted of two approaches and landings. The pilot could make comments at any time, however, formal use of the comment card (Figure 10), Cooper-Harper scale (Figure 11), and the PIO scale (Figure 12) was made after the second landing for the configuration. The pilot had the option of a third landing on a configuration and in that case the comments and gradings were made after the third landing.

The pilot comments and ratings were considered the primary data of the investigation, and were recorded on voice tape (Appendix F are the transcripts of these comments). In addition, the flight test engineer (in the right evaluation seat) manually recorded comment summaries, touchdown dispersion, and pilot ratings (Appendix E). At the end of each flight the flight test engineer would use this data to determine configurations for the next flight.

3.8 DATA RECORDINGS

In addition to voice tapes a 58 channel digital recorder was used to record signals of interest. These included:

1. Pilot inputs
2. Control surface motions
3. Aircraft states (model and TIFS)
4. Radar altitude
5. Sink rate
6. Turbulence inputs

A specific list of recorded variables is presented in Appendix J.

PILOT COMMENT CARD

1. Feel
   - Column, wheel forces and displacements, harmony
   - Roll and pitch sensitivity

2. Response to inputs required to perform task
   - Roll and pitch
     - initial response
     - predictability of final response
     - pitch/roll harmony
     - special pilot inputs - why?
     - tendency to PIO
     - sensitivity (gearing)

3. Airspeed control (autothrottle OFF)

4. Approach performance
   - ILS: glideslope, localizer capture and tracking
   - Visual: flight path corrections

5. Flare and touchdown
   - Problems with line-up flare, touchdown, tendency to float
   - Any unusual motions, visual cues, etc.
   - Any unusual control techniques required

6. Approach vs. landing
   - Which more difficult

7. Effects of turbulence/wind

8. Summary (brief)
   - Good features
   - Problems

9. Overall Cooper-Harper Rating - PIO Rating

Figure 10 PILOT COMMENT CARD

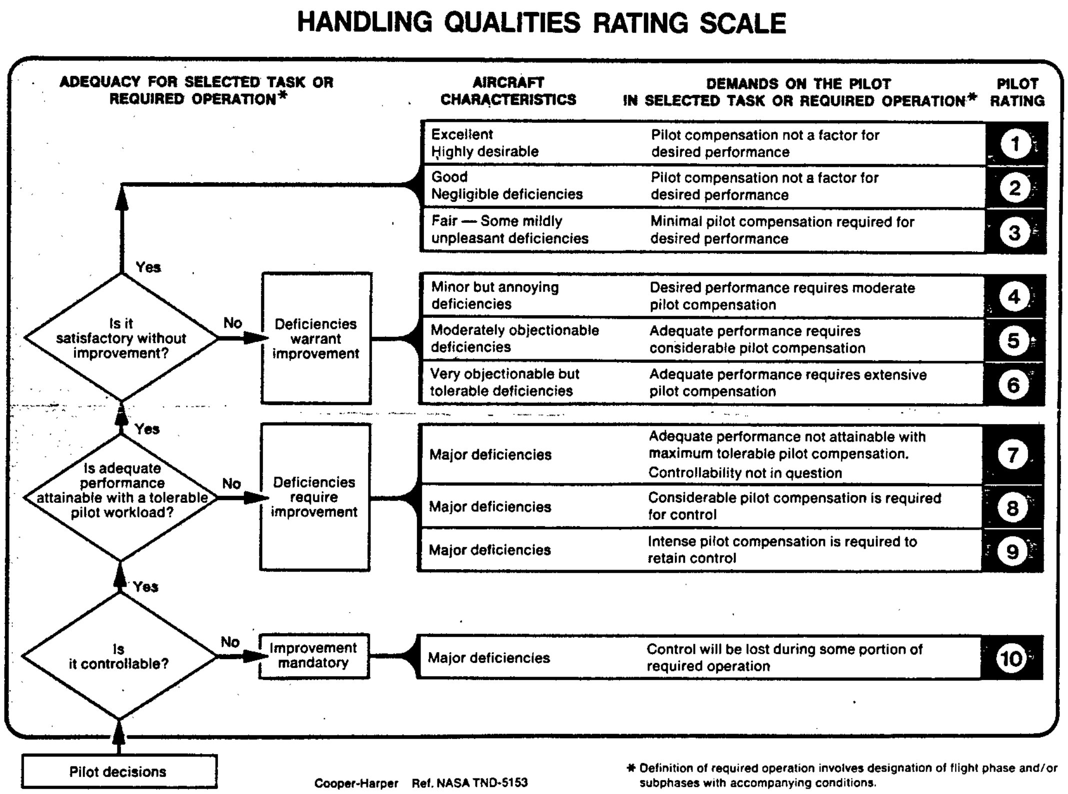


Figure 11 COOPER-HARPER HANDLING QUALILTIES RATING SCALE

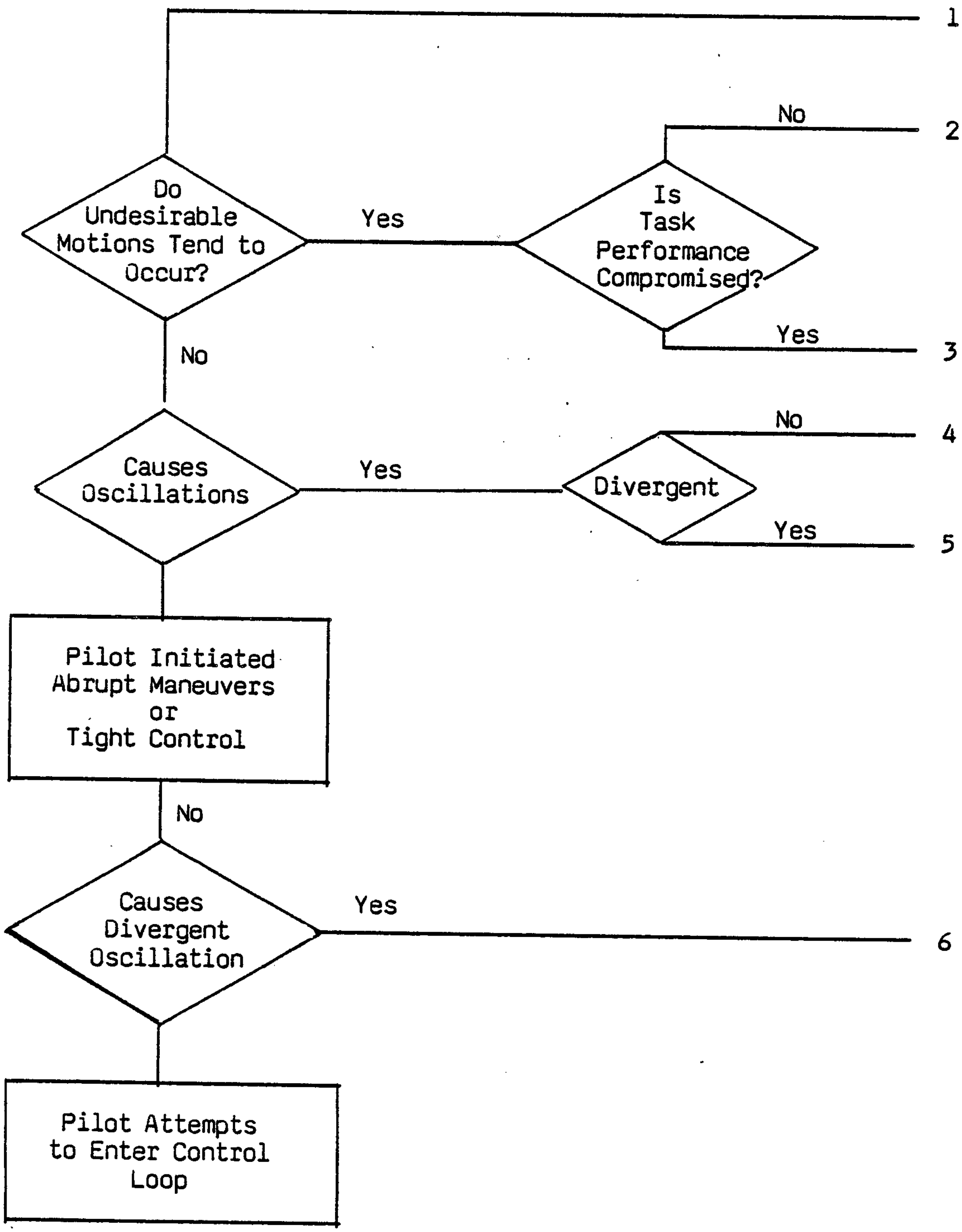


Figure 12 PIO TENDENCY CLASSIFICATION

Section 4
EXPERIMENT RESULTS AND ANALYSIS

4.1 INTRODUCTION

An original intent of the experiment was to learn more about the paradox of flight control systems using integral/proportional pitch rate feedback as applied to the flared landing task. Although these control systems are designed to existing specifications (normally the Level 1 requirements of the classical criteria i.e., MIL-F-8785, equivalent systems, Neal-Smith etc.) their performance in the flared landing is generally not Level 1 and can be as bad as Level 3. A primary goal of this "learning process" was to investigate the significance of pitch rate overshoot for these systems.

A co-author, Mr. C. Chalk (Chalk, Calspan TIFS Memo - 1002) proposed a method of providing increased bandwidth (i.e., quickness, pitch rate overshoot, etc.) using a lead/lag filter in the command path which would place a pole at the position of the control system zero, and place a zero at the position of the λ_2' augmented pole. This would restore the effect of the $1/\tau_{\theta_2}$ zero and thus restore the quickness of the α response hopefully resulting in a more "conventional" aircraft response.

At the time this experiment was about to get underway it was becoming apparent to the author that what pilots like most about these integral/ proportional pitch rate systems is the excellent up and away theta control, i.e., pitch pointing characteristics, and this excellent pitch pointing is reflected in classical criteria analysis. What pilots like least about these systems is the necessity to push, or reverse stick forces in the landing flare (conventional aircraft, with phugoids, require monotonic stick forces, i.e., modulation of back pressure, as opposed to combination of back and forward pressure on the control, in the landing flare). When presented with this opinion the co-author (Mr. Chalk) proposed a washout filter in the command path. Pilots are generally skeptical of washouts in their controls, however, engineering pilots are broadminded enough to try them in a controlled experiment thus the washout filter became a part of the test matrix.

The test matrix (described in Section 2) consisted of "conventional" pitch rate control systems of various pitch rate short period frequencies (all

within the Level 1 boundaries of MIL 8785C) at various magnitudes of $1/\tau_{\theta_2}$, and modified by application of the lead/lag and washout pre-filters. Some of these configurations were "shuttle like" and two neutral static stability cases were included in order to observe effects due to the integrator alone, if any. Also included was a conventional Level 1 aircraft. The results of the experiment as well as an analysis of the data will be presented in the following paragraphs. Some of the results were rather dramatic and somewhat unexpected, particularly as regards effects of the washout pre-filter. The preliminary analysis was difficult in that correlation between the ratings and configurations was not apparent. Considerable time was spent in study of the time histories in an attempt to identify parameters that would correlate the data. As the analysis progressed and correlations began to emerge it became apparent that a product of the analysis could be a time domain criteria for predicting flying qualities. A detailed description of this criteria and some test applications are presented in the analysis paragraphs below.

4.2 EXPERIMENT RESULTS

4.2.1 Verification of Data

The primary data of this experiment was pilot ratings and comments. Pilot ratings are shown in Table 1 of Appendix K and graphically on Figure 13. Pilot comments are in Appendix F. Pilot rating data was verified to be consistent with task performance standards by comparing the flight test engineer's flight summary (Appendix E) with the pilot comment transcripts.

In addition, digital records from all data flights were reviewed to assure that the correct configuration model and command gains were used for each evaluation and to confirm adequate model following. There were no configuration model errors, however, three evaluations were discarded:

1. Flight 733, Configuration 3-2-4 was discarded due to poor alpha model following. The cause is believed to be over active throttle commands by the evaluation pilot.

2. Flight 741, Configuration 3-2-4 was discarded for the same reason as above.

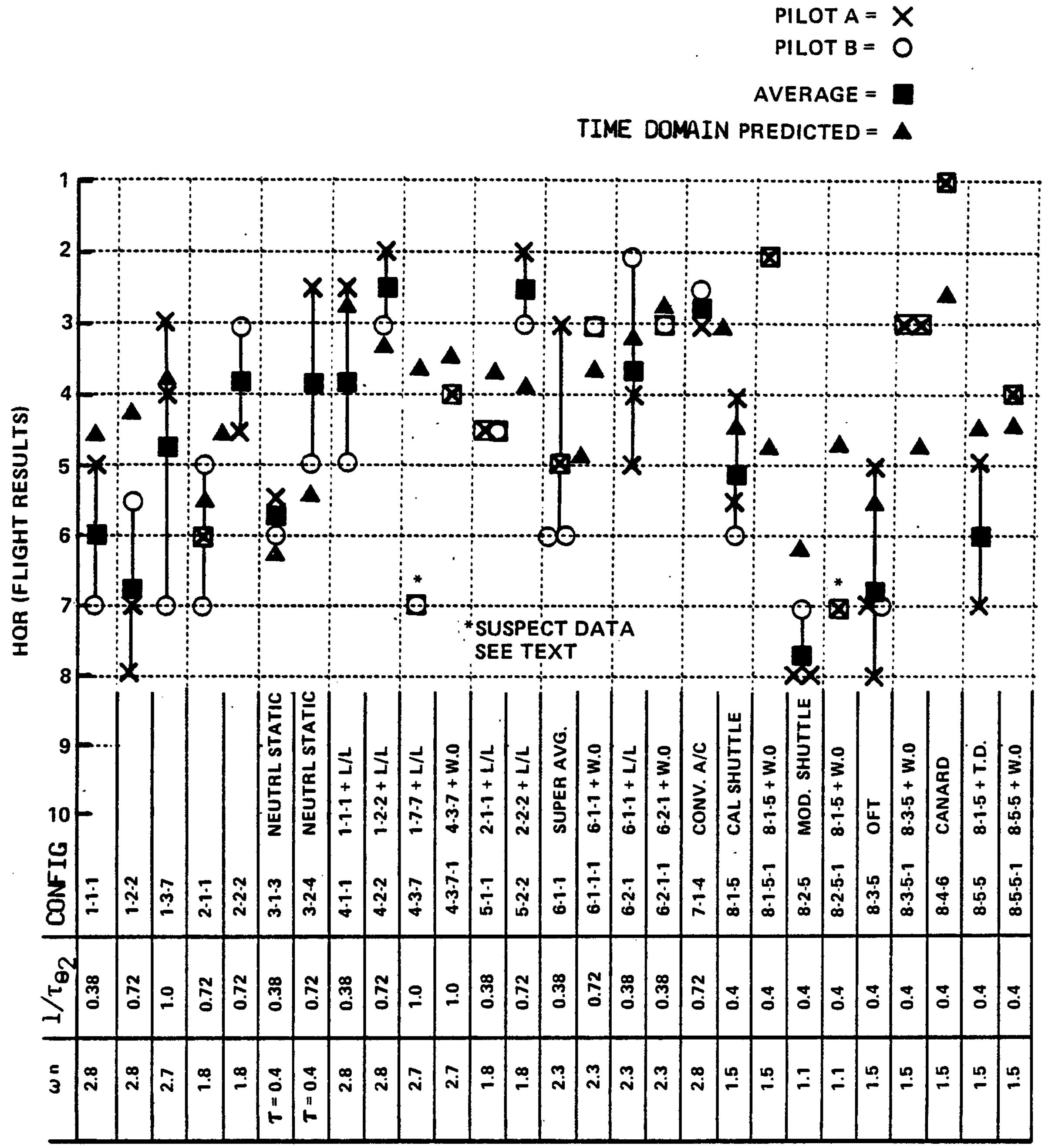


Figure 13 PILOT RATINGS

3. Flight 734, Configuration 8-2-5 was discarded due to an incorrect command gain setting.

Two additional evaluations are suspect:

1. Configuration 4-3-7, this was a single evaluation by one pilot. This data plots "out in left field" with any criteria and correlation attempted. It is shown on all the data plots but is felt to be an anomalous data point.

2. Configuration 8-2-5-1, this again was a single evaluation by one pilot. The safety pilot considered this evaluation invalid due to pilot technique. It is shown on all data plots but is felt to be an invalid data point.

Figure 14 is a pilot rating deviation curve and shows a slight bias towards Pilot A for better ratings (better flying qualities). This bias was effectively eliminated by using average pilot rating for all data analysis. The development of these average ratings is shown in Table 1 of Appendix K.

4.2.2 Review of Data Results

A preliminary review of the data was conducted to identify trends.

4.2.2.1 Effects of Changes in Short Period Frequency (ω_n)

Figure 15 shows the effect of changing frequency (ω_n) from 2.8 rad/sec to 1.8 rad/sec. There appears to be no effect at $1/\tau_{\theta_2}$ values of 0.38 and an improvement in rating when going to the lower frequency at $1/\tau_{\theta_2}$ values of 0.72. However, this data base is small and no substantial trends can be justified. As all of these configurations are within the Mil Spec 8785 Level 1 boundary for ω_n and $1/\tau_{\theta_2}$ one would not expect a substantive trend. In fact the improvement from configuration 1-2-2 to configuration 2-2-2 would not be expected.

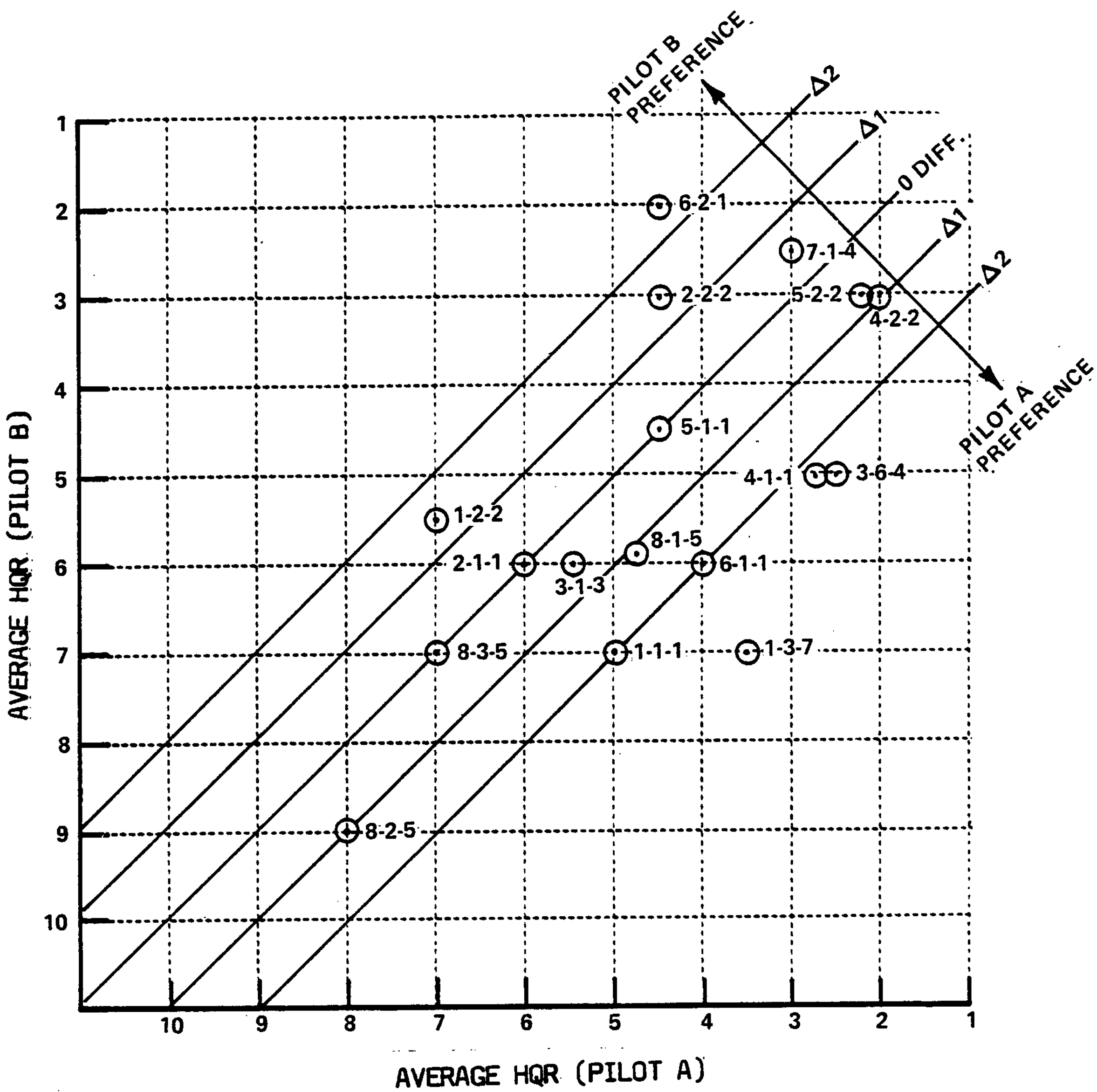


Figure 14 PILOT RATING DEVIATION

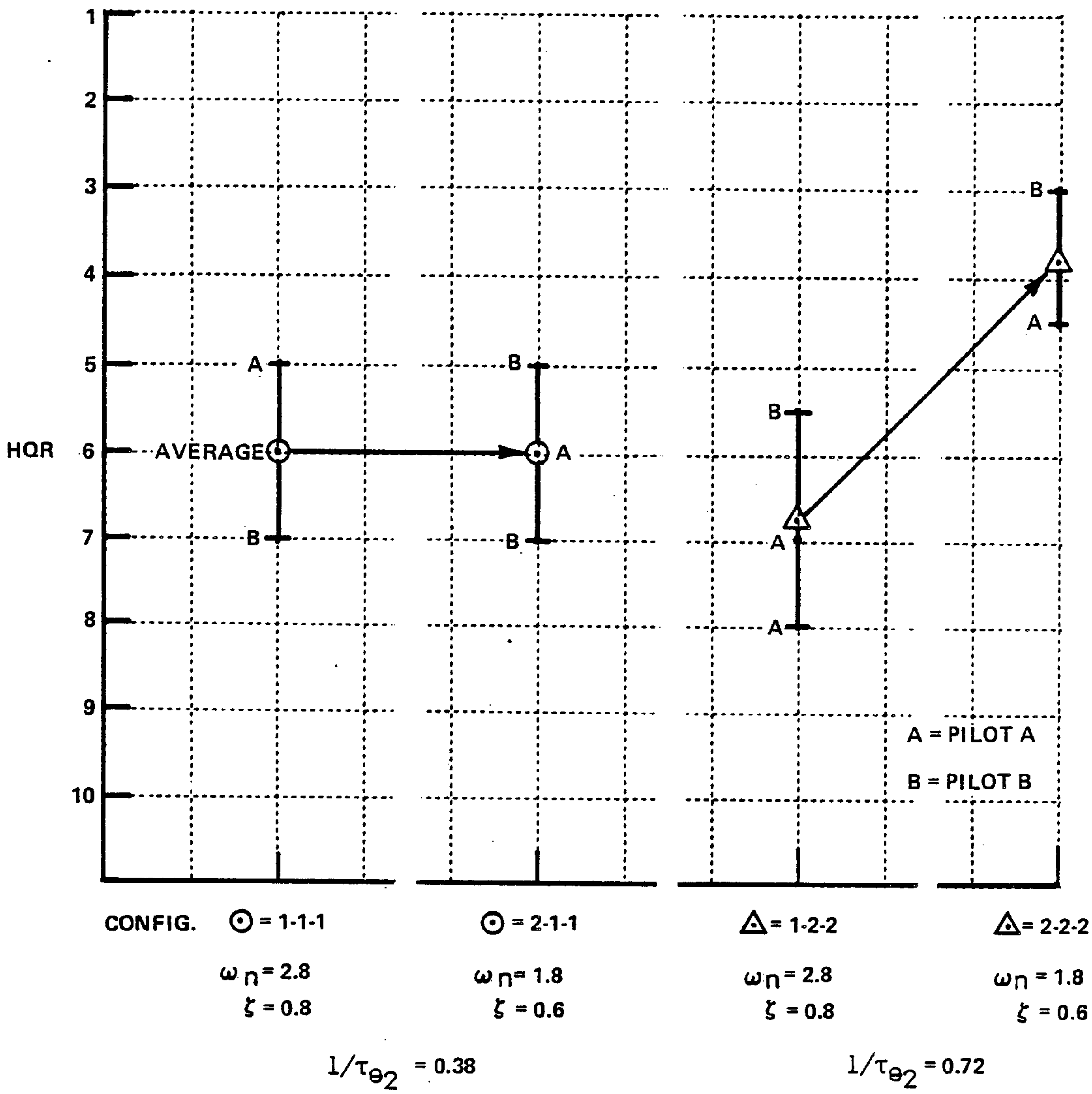


Figure 15 EFFECT OF VARYING ωn WITH "CONVENTIONAL" INTEGRAL - PROPORTIONAL PITCH RATE FEED BACK AT TWO VALUES OF $1/\tau_{\theta 2}$

4.2.2.2 Effects of Changing $1/\tau_{\theta_2}$

Figure 16 shows the effect of increasing $1/\tau_{\theta_2}$ on the basic pitch rate flight configurations. The improvements shown by configurations 2-1-1/2-2-2 and 3-1-3/3-2-4 would be expected when increasing from a rather low $1/\tau_{\theta_2}$ value of 0.38 to a more nominal 0.72. On the other hand, the reverse trend of configurations 1-1-1/1-2-2 is not what one would expect and a review of Figure 15 makes the rating of configuration 1-2-2 appear suspect. A review of the flight data showed correct model parameters and good model following for this configuration. Additionally, this configuration was evaluated three times by two pilots on three different flights and there is no justification for considering this data point invalid. Configuration 1-2-2 is, however, the only case in the experiment where going from $1/\tau_{\theta_2}$ = 0.38 to $1/\tau_{\theta_2}$ =0.72 did not improve the rating by one to two numbers.

Changing $1/\tau_{\theta_2}$ for configurations with the lead/lag filter incorporated and the neutral stability cases are shown on Figure 17. The improvement from $1/\tau_{\theta_2}$ = 0.38 to $1/\tau_{\theta_2}$ = 0.72 is well documented by this data. However, configuration 4-3-7 shows a reverse trend for a value of $1/\tau_{\theta_2}$ = 1.0. As previously stated it is felt that the evaluation of configuration 4-3-7 is felt to be an anomalous data point and may not justify a conclusion that a value of $1/\tau_{\theta_2}$ = 1.0 would be bad for these control systems.

4.2.2.3 Effect of the Lead/Lag Pre-Filter

The lead/lag pre-filter was guite effective in improving pilot ratings as can be seen in Figure 18 and 19. In all cases the lead/lag filter improved ratings and in four of six cases the lead/lag filter brought Level 2 and Level 3 configurations up to Level 1, and in the other two cases up to borderline Level 1.

This significant result makes a strong argument for the opinion that pitch rate overshoot (as in conventional aircraft) is not detrimental and may be required to achieve the desired α (and subsequent γ) response required for the landing task.

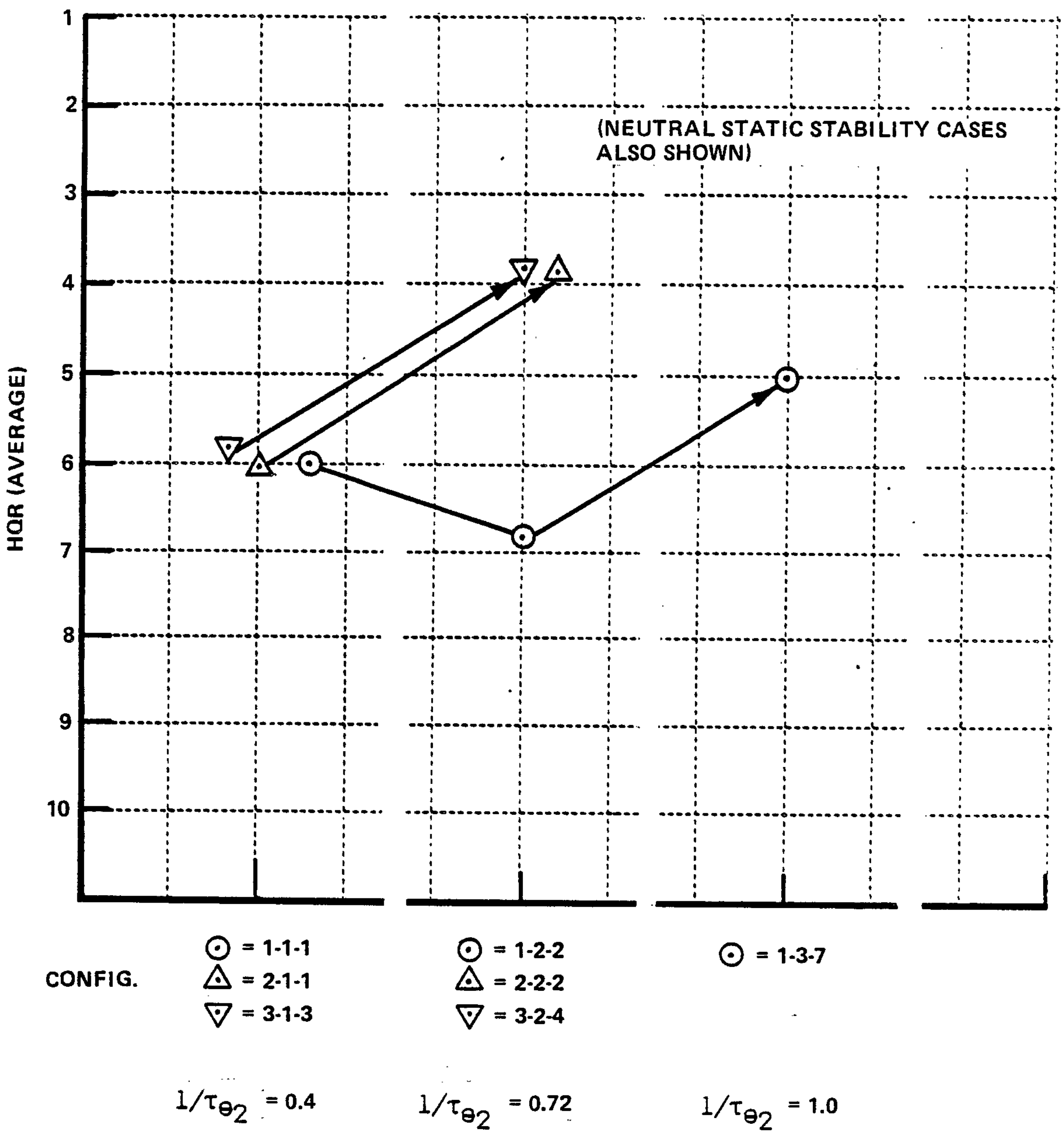


Figure 16 EFFECT OF VARYING $1/\tau_{\theta_2}$ WITH "CONVENTIONAL" INTEGRAL-PROPORTIONAL PITCH RATE FEED BACK (NO LEAD/LAG OR WASHOUT)

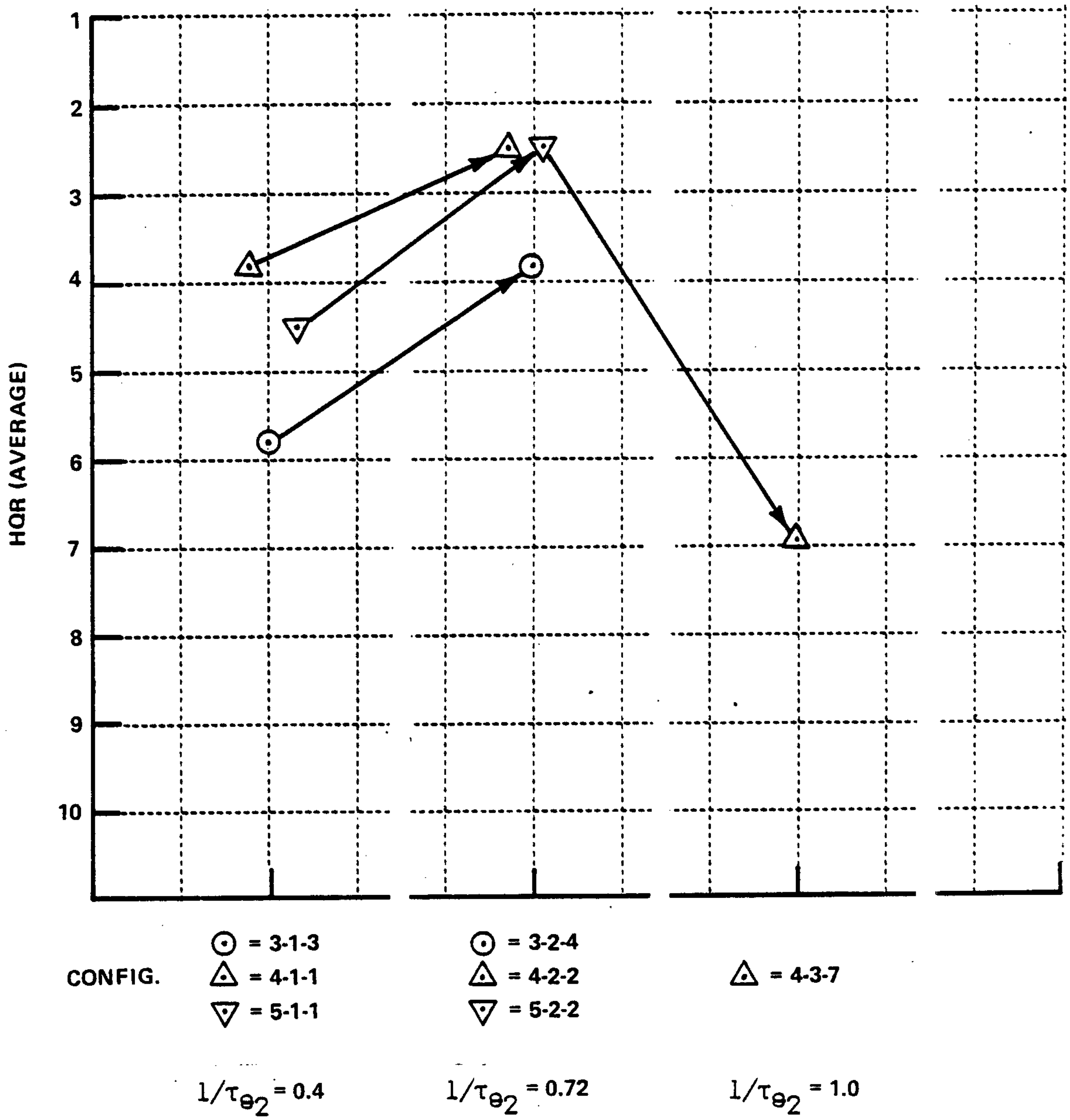
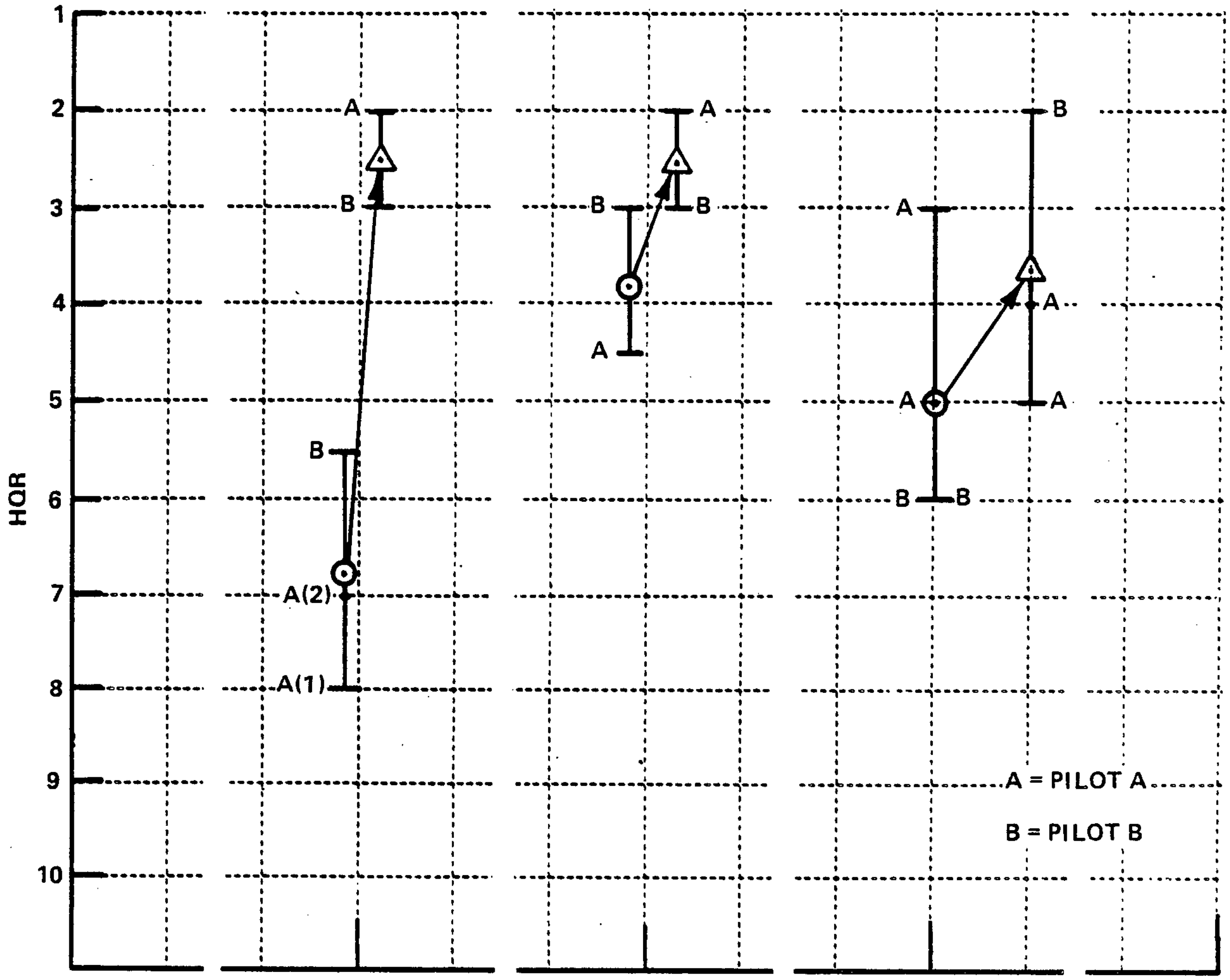


Figure 17 EFFECT OF VARYING $1/\tau_{\theta 2}$ WITH LEAD/LAG PRE-FILTER (INCLUDES NEUTRAL STATIC CASE)



CONFIG	⊙ = 1-2-2 △ = 4-2-2	⊙ = 2-2-2 △ = 5-2-2	⊙ = 6-1-1 △ = 6-2-1
ω_n	2.8	1.8	2.3
ζ	0.8	0.6	0.5
$1/\tau_{\theta_2}$	0.72	0.72	0.38

Figure 18 EFFECT OF LEAD/LAG PRE-FILTER AT THREE VALUES OF ω_n AND $1/\tau_{\theta 2}$ (INCLUDING SUPER AUGMENTED CASES)

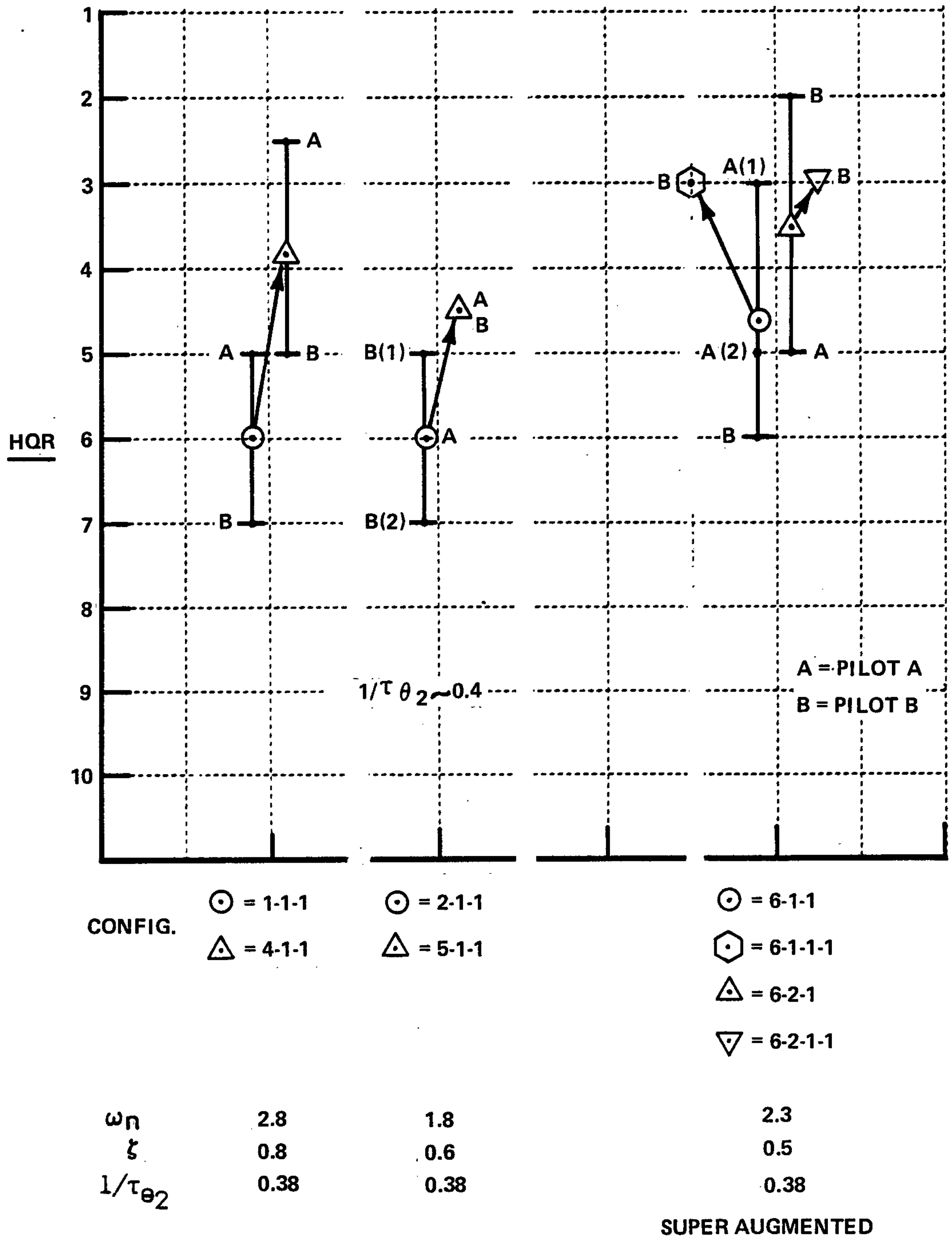


Figure 19 EFFECTS OF LEAD/LAG AND WASHOUT PREFILTERS AT $1/\tau_{\theta_2} \sim 0.4$ (NON SHUTTLE LIKE CONFIGURATIONS)

4.2.2.4 Effects of the Washout Pre-Filter

The results of the washout filter are shown in Figure 20. The washout filter was applied to seven configurations. In four of these cases the ratings were raised from Level 2 and 3 to Level 1. In two cases the improvement was to borderline Level 1, and in one case there was no improvement in level. The latter case was configuration 8-2-5-1 which was considered by the safety pilot to be a questionable data point.

In the case of the shuttle OFT configuration (8-3-5) the washout was applied on two occasions, and during the last flight the OFT with and without washout was flown on back to back evaluations. In all cases the improvement was from Level 3 to Level 1.

Had the dramatic improvement resulting from the washout filter been foreseen more of the flight test would have been applied to it. As it was, the filter was not applied until the latter stages of the flight program and consequently the exposure was less than desired.

4.2.2.5 Effect of Neutral Static Stability

Previous informal test flights in the Calspan Learjet indicated that there might be a flying qualities difference between a rate-command, flight control system attained by neutral static stability and one attained by integral/proportional pitch rate feedback. It was also felt that since the neutral static stability case had no pitch rate overshoot at all, it would be of interest to evaluate.

Configurations 2-1-1 and 2-2-2 were observed to have similar pitch rate step responses as the neutral static configurations 3-1-3 and 3-2-4 (Appendix A, time histories) and were chosen for comparison. Figure 21 shows no change in ratings between the two sets. It appears that how rate command is achieved is transparent to the pilot. It also appears that other things being equal (i.e., time delay, time to steady state, sensitivity, etc.) there may be no flying qualities differences between no pitch rate overshoot and small amounts (~ 25%) of overshoot in pitch rate.

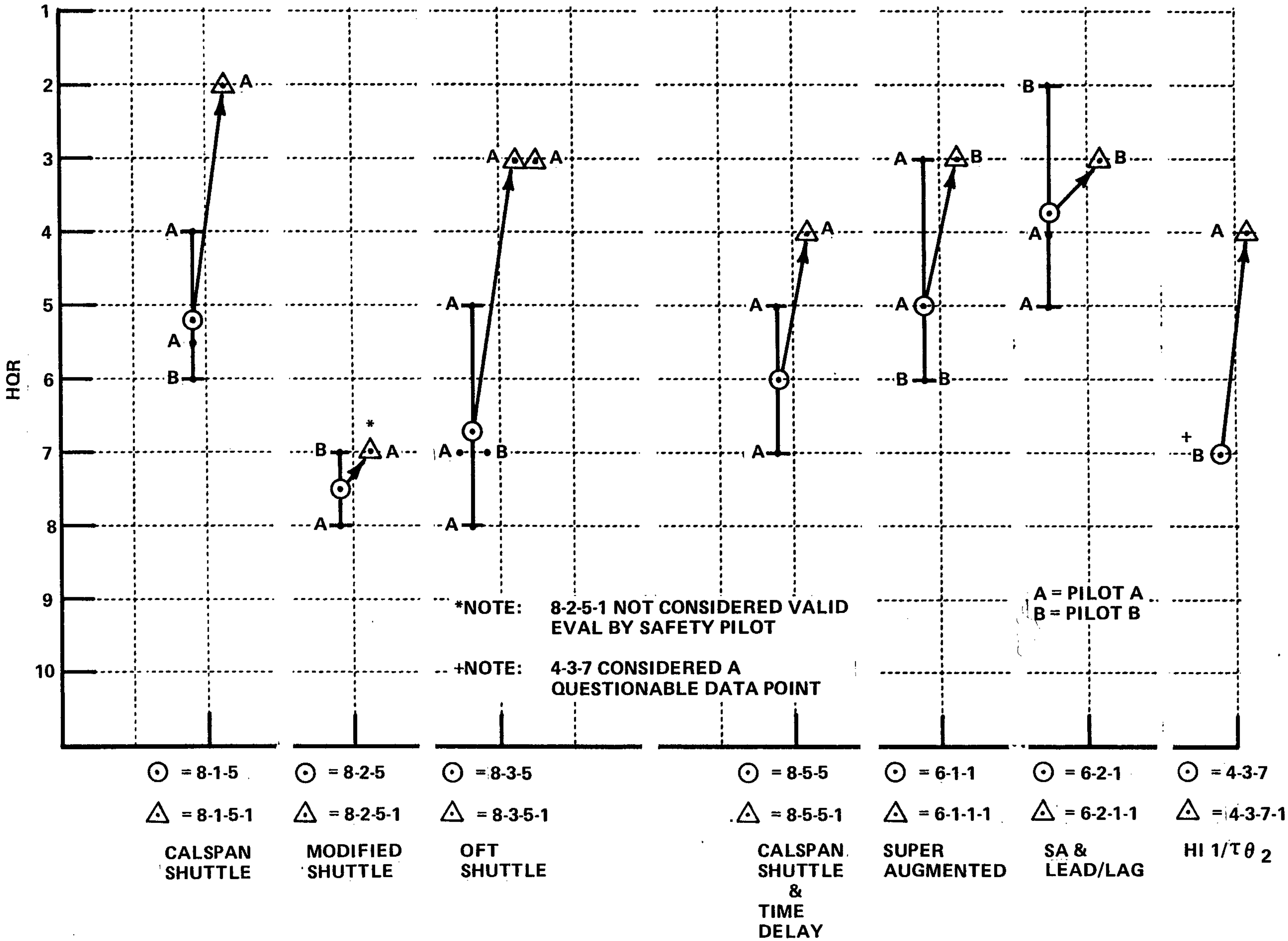


Figure 20 EFFECT OF WASHOUT PRE-FILTER

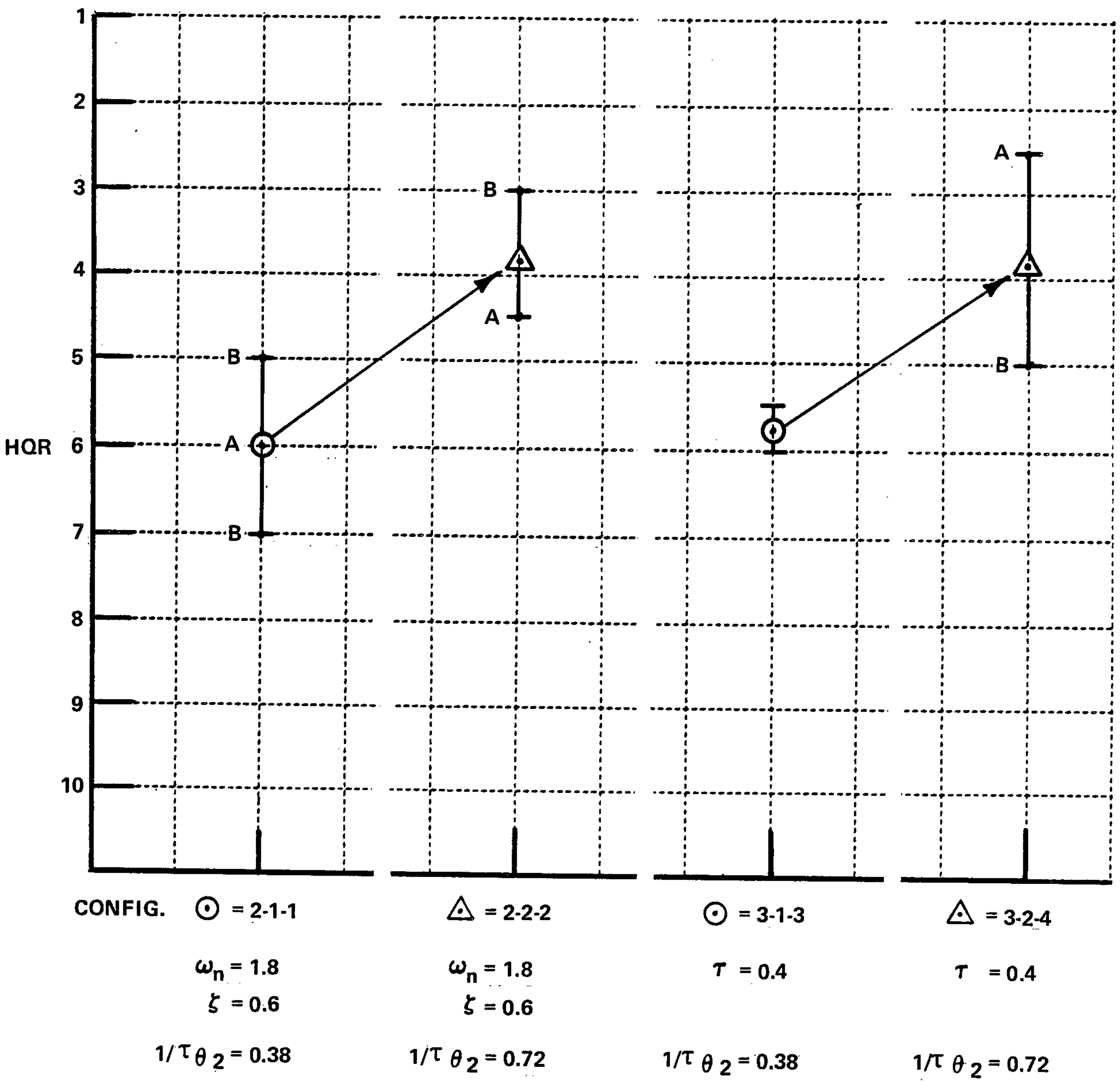


Figure 21 EFFECTS OF NEUTRAL STATIC STABILITY WITH CHANGES IN $1/\tau_{\theta_2}$

4.2.2.6 Summary of Results

- The range of short period frequency in this flight experiment was limited and consequently no significant frequency effects were observed.

- Performance generally improved when increasing $1/\tau_{\theta_2}$ from 0.38 to 0.72. Trends of higher values of $1/\tau_{\theta_2}$ were inconclusive due to limited data.

- Designing a pitch rate control system to exhibit short term responses as observed in conventional Level 1 aircraft, will improve the landing performance of integral-proportional pitch rate flight control systems.

- A lead/lag pre-filter, that cancels the control system zero and restores the $1/\tau_{\theta_2}$ zero of such systems, will provide the necessary short term response characteristics and result in improvement in performance and pilot rating.

- Integral-proportional pitch rate flight control systems (rate command attitude hold) suffer performance degradation in the landing flare. This is, in part, because the responses to stick commands are q, $\dot{\alpha}$ and $\dot{\gamma}$ at low frequency rather than θ, α and γ.

- When a washout pre-filter is added to the integral-proportional pitch rate systems, the low frequency responses to stick commands are θ, α and γ. This characteristic permits the pilot to use proportional control rather than impulse control and provides control feel throughout the flare maneuver.

- There was no significant difference between neutral static stabililty configurations and integral-proportional pitch rate control systems of similar properties.

4.2.3 Analysis of Data

An expected result of this flight experiment was that the lead/lag pre-filter would improve pilot ratings for the final approach and landing, and the results showed the order of improvement expected. However, the dramatic improvement in pilot ratings due to the washout pre-filter was not expected.

The analysis was complicated by these unexpected results in that a reason for the level of improvement attained should be determined, both in an analytical sense and a physical sense. A preliminary study of the time histories, Bode plots, root locus plots, transfer functions, etc., did not disclose readily apparent answers. It was decided to proceed with the analysis in two basic thrusts. The first was an analysis utilizing the "classical" frequency domain criteria i.e., Equivalent Systems, Neal-Smith, and Bandwidth. A co-author, Mr. Sarrafian of NASA Dryden, proceeded with this phase of the anlaysis utilizing the computer facilities at Dryden. The author tried a different approach by working in the time domain i.e., time history analysis. The remaining co-author Mr. Chalk, also of Calspan, acted as mentor to both thrusts.

As all configurations tested were verified by a thorough review of flight data recordings (and inaccurate data points were appropriately discarded), both analyses were conducted on analytical data using computer generated transfer functions, time histories, Bode plots, etc., much as a designer would do.

4.2.3.1 Frequency Domain Analysis

The configurations (in their analytical form) were evaluated using lower-order equivalent systems analysis (Reference 5), bandwidth criterion (References 6 and 7), and Neal-Smith analysis (Reference 8). An attempt was also made to correlate the bandwidth frequencies of altitude rate at the pilot station with the pilot ratings, similar to the methods used in Reference 10. It should be emphasized that 50 - 60 ms of additional time delay (depending upon the configuration) was implemented into each configuration in the analysis to match the amount of time delay seen by the pilots on TIFS. The pilot ratings used in this analysis are presented in Tables 1 and 5. These ratings

were averaged between the two evaluation pilots who participated in the program.

- **Equivalent Systems Analysis**

The longitudinal lower-order equivalent systems results are presented in Table 6, Appendix K. The results were obtained using a single fit to the closed-loop $\dot{\theta}/F_{ES}$ frequency response with a fixed value of L_α. This method assumes a theoretical relationship between $\dot{\theta}$ and n_z (Reference 11). The lower-order transfer function is of the form:

$$\frac{\dot{\theta}}{F_{ES}} = \frac{K_{\dot{\theta}}\,(s + L_\alpha)e^{-\tau s}}{s^2 + 2\zeta_{sp}\omega_{sp}\,s + \omega_{sp}^2}$$

and is matched through the frequency range of 0.3 to 10.0 rad/sec, a range typically used for equivalent systems matching (Reference 11). Note that this range does not include the washout frequency of 0.2 rad/sec. The results were compared to the MIL-F-8785C criteria for Category C, Class III - type aircraft.

Most configurations achieved a good fit to the lower-order system (cost functions less than 20). The short period frequency and damping are Level 1 for most configurations. The equivalent time delays are Level 2 for most configurations, although some display Level 3 characteristics. An overall Level rating is presented to indicate the most conservative estimate of the handling qualities for each configuration. Despite the degradation of all the configurations due to equivalent time delay, pilot comments did not reflect this trend. The inability of the equivalent systems analysis to correlate to the pilot rating trends leads to the conclusion that this type of analysis (i.e., $\dot{\theta}$ match and only L_α fixed) is inadequate for this data. (See Table 2 and Table 9, Appendix K).

- **Bandwidth Criterion**

The bandwidth criterion (References 7 and 8) was applied to the closed-loop pitch attitude transfer function (θ/F_{ES}) for each configuration. The bandwidth is defined as the crossover frequency at which the phase margin is 45 degrees or the gain margin is 6 dB, whichever frequency is lower. The phase delay is defined as:

$$\tau = -(\phi + 180^{\circ})/(57.3\omega)$$

where ω is defined to be two times the frequency at which the phase = -180° and ϕ is the phase at ω. The bandwidth criterion was not applied with a droop correction factor, as discussed in Reference 8. Reference 8 points out that the original bandwidth criterion is conceptually similar to the revised version.

The bandwidth criterion results are presented in Table 7 Appendix K using Category C flight phase boundaries (Figures 22, 23, and 24). Configurations 1-7 are shown to have Level 2 handling qualities, with no discrimination between configurations with and without a pre-filter or a washout filter in the command path. This trend is not consistent with the pilot ratings. The shuttle configurations (configuration 8) are also Level 2 with the exception of 8-3-5 (OFT) and 8-5-5 (Calspan + 35 ms time delay), which were Level 3. The washout filter did not appear to significantly improve the Level rating according to the bandwidth criterion, contrary to the pilot ratings. Overall, the bandwidth criterion did not appear to satisfactorily explain the pilot ratings. (See Table 9 Appendix K).

- **Neal-Smith Analysis**

The Neal-Smith closed-loop handling qualities criterion was used to analyze the compensation required by the pilot to close the loop on θ/F_{ES} in the landing task for all TIFS configurations. The details of the criterion are presented in Reference 8. The revised boundaries for maximum closed-loop resonance and pilot compensation required for the landing task were applied to the data, as described in Reference 12. In cases where the maximum closed-loop resonance was less than -2 dB, a droop constraint of -2 dB was used as

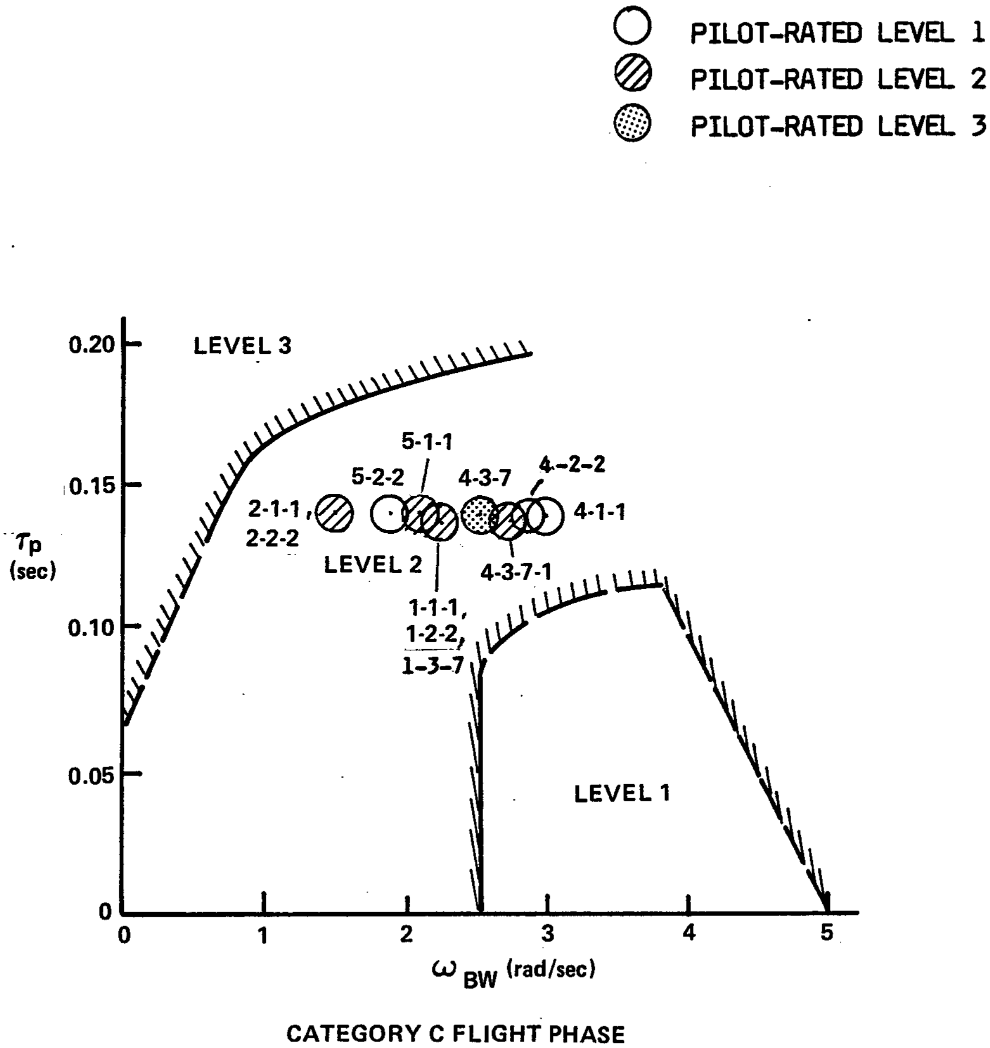


Figure 22 BANDWIDTH CRITERION RESULTS CONFIGURATIONS 1, 2, 4, 5

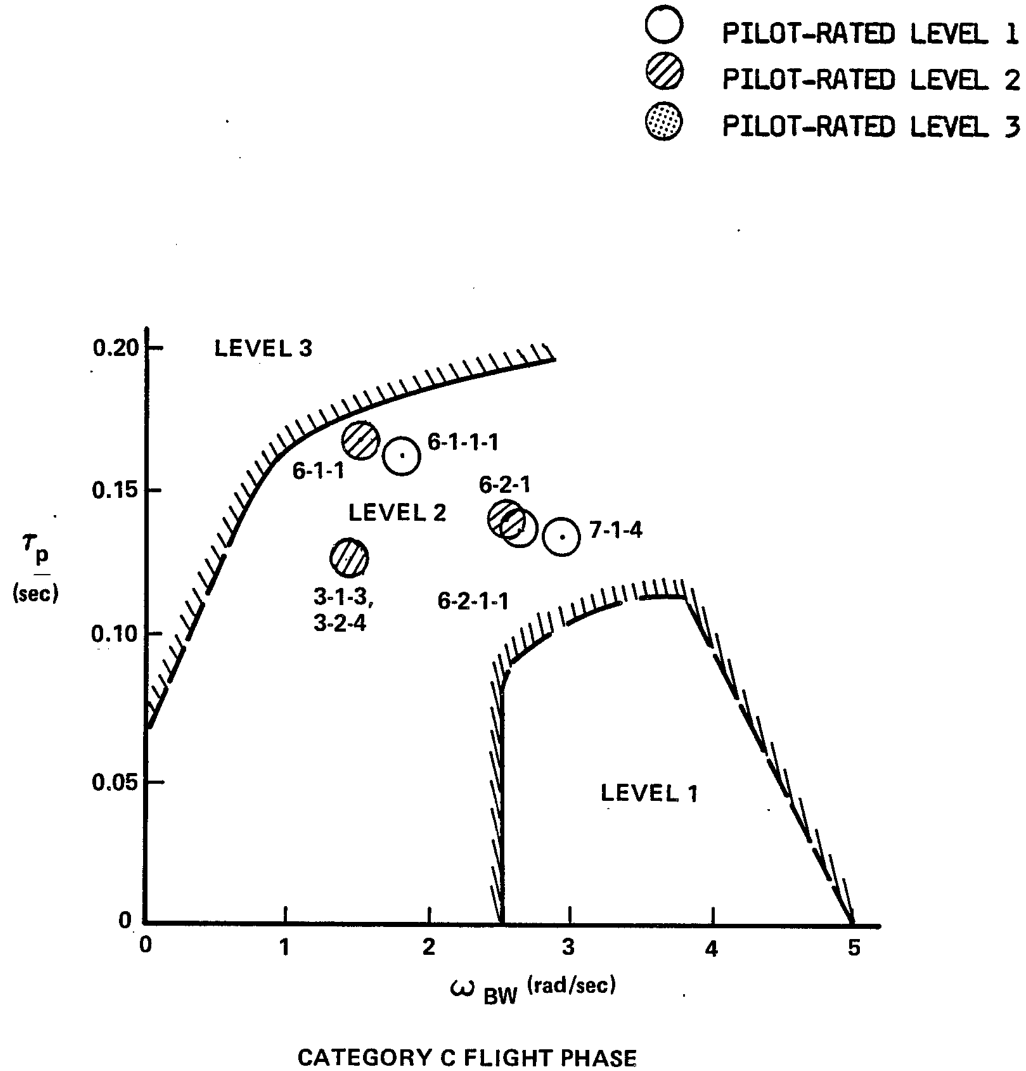


Figure 23 BANDWIDTH CRITERION RESULTS CONFIGURATIONS 3, 6, 7

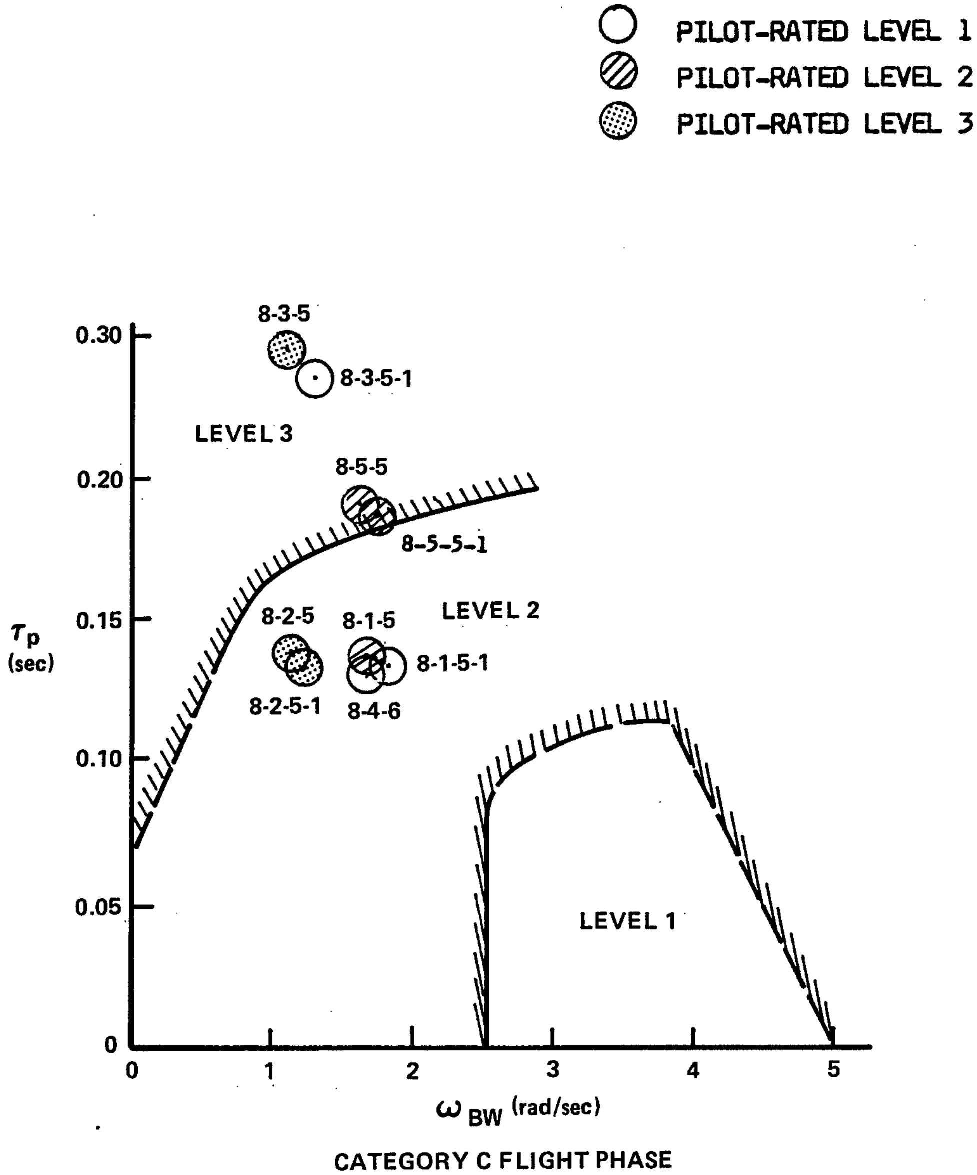


Figure 24 BANDWIDTH CRITERION RESULTS CONFIGURATION 8

opposed to the standard minimum droop of -3 dB. This condition was met simultaneously with a -90° closed-loop phase constraint. The pilot model used in this analysis was:

$$Y_{p_\theta} = K_p e^{-\tau s} (\tau_{LEAD}\, s + 1)/(\tau_{LAG}\, s + 1)$$

where the pilot's neuromuscular time delay, τ, is 250 ms. This value is based on the pilot model time delay used in Reference 10. The bandwidth frequency range covered in this analysis was 1.0 - 4.0 rad/sec. Configurations 6-2-1 and 6-2-1-1 experienced convergence problems in this frequency range and did not achieve satisfactory solutions.

The results of the maximum closed-loop resonance achieved and pilot compensation required for increasing bandwidths are presented in Figures 25 thru 43 for all configurations (Figure 25 is typical). Pilot rating predictions resulting from the Neal-Smith analysis were made using a single bandwidth frequency. This bandwidth frequency was selected by linearly interpolating relative to the Neal-Smith boundaries and assigning a pilot rating for each bandwidth frequency. A bandwidth frequency was then selected which provided pilot ratings that best compared to the average pilot ratings determined in flight. A bandwidth frequency of 2.0 provided the best correlation between Neal-Smith predicted and actual pilot ratings. Figure 44 illustrates the results of this pilot rating comparison. It should be noted that pilot rating data generally varies at least + or - 1 Cooper Harper rating. The trend shown in Figure 44, however, does not appear to be hinged upon that point. The Neal-Smith pilot ratings predicted most configurations to be better than the actual ratings recorded. This implies that despite the good pitch-pointing qualities of these configurations, the actual pilot ratings were not reflecting this feature. It appears that the pilot's attention may be strongly influenced by a parameter other than pitch attitude in the landing task.

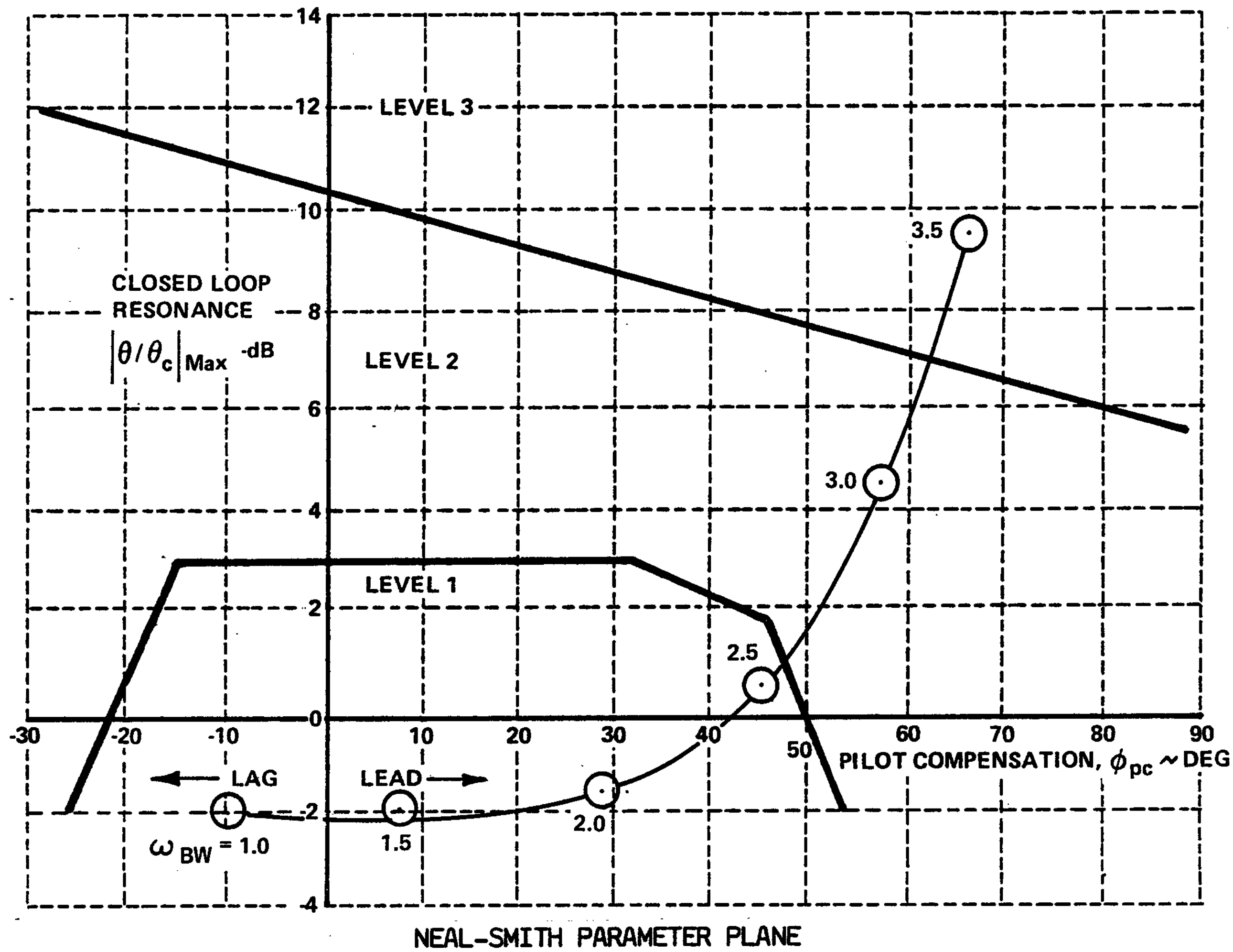


Figure 25 CONFIGURATION 1-1-1 (2 dB DROOP)

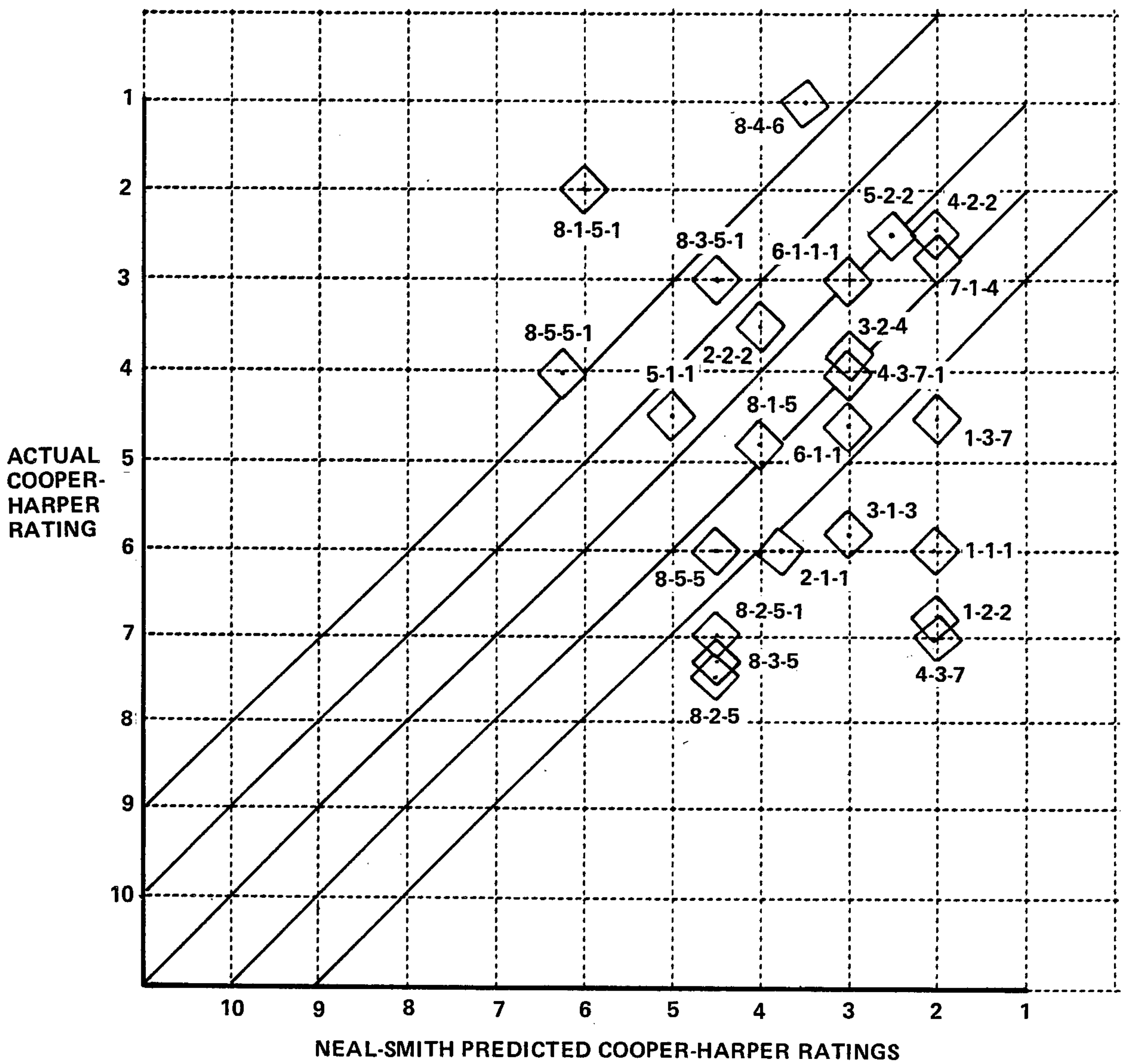


Figure 44 COMPARISON OF ACTUAL PILOT RATINGS AND NEAL-SMITH PREDICTED PILOT RATINGS ($\omega_{BW} = 2.0$)

- **Altitude-Rate Bandwidth Analysis**

In an attempt to distinguish the improvement in pilot ratings with the addition of a prefilter and command washout filter to some of the configurations, a correlation was made between altitude rate at the pilot station and pilot ratings. Pilot comments had indicated that altitude rate control was a significant factor in the evaluation of pilot performance. The altitude-rate transfer function ($\dot{h}_p/F_{ES}$) used in this analysis was the following:

$$\frac{\dot{h}_p}{F_{ES}} = \frac{g(N_{zcg} \text{ numerator})}{s(\text{C.E.})} + \frac{L_p(\dot{\theta} \text{ numerator})}{(\text{C.E.})}$$

where C.E. is the characteristic equation of the configuration and L_p is the distance from the c.g. to the pilot station. ℓ_p was maintained at a value of 34 ft throughout the evaluation. A direct-loop closure was made on the altitude rate transfer function using the following pilot models:

$$Y_{ph} = K_{ph}\, e^{-\tau s}$$

the pilot time delay was 250 ms. The uncompensated frequency response curve was plotted on a Nichols chart over the frequency range 0.1 to 10.0 rad/sec. The curve was then shifted to be tangent to the 3 dB maximum closed-loop resonance curve. The bandwidth was then determined as the frequency which provided -90° of closed-loop phase. This procedure is similar to that used in Reference 10 for altitude closure following a closure of the attitude loop.

The altitude-rate bandwidth frequencies are presented in Table 8 Appendix K and are plotted against the actual pilot ratings in Figure 45. The boundaries shown in Figure 45 encompass those configurations where pilot comments indicated a strong influence of altitude-rate control. An overall trend of improved pilot ratings with increasing altitude bandwidth is evident. The trend in Figure 45 indicates an improvement in pilot ratings with increasing altitude-rate bandwidth, although the curve does not appear linear. This relationship does not point out a significant increase in altitude-rate bandwidth with the addition of a lead/lag pre-filter (Configurations 4, 5, 6-2). The magnitudes of these bandwidths appear to be in the vicinity of the bandwidth for the conventional aircraft (Configuration 7). Both the conventional

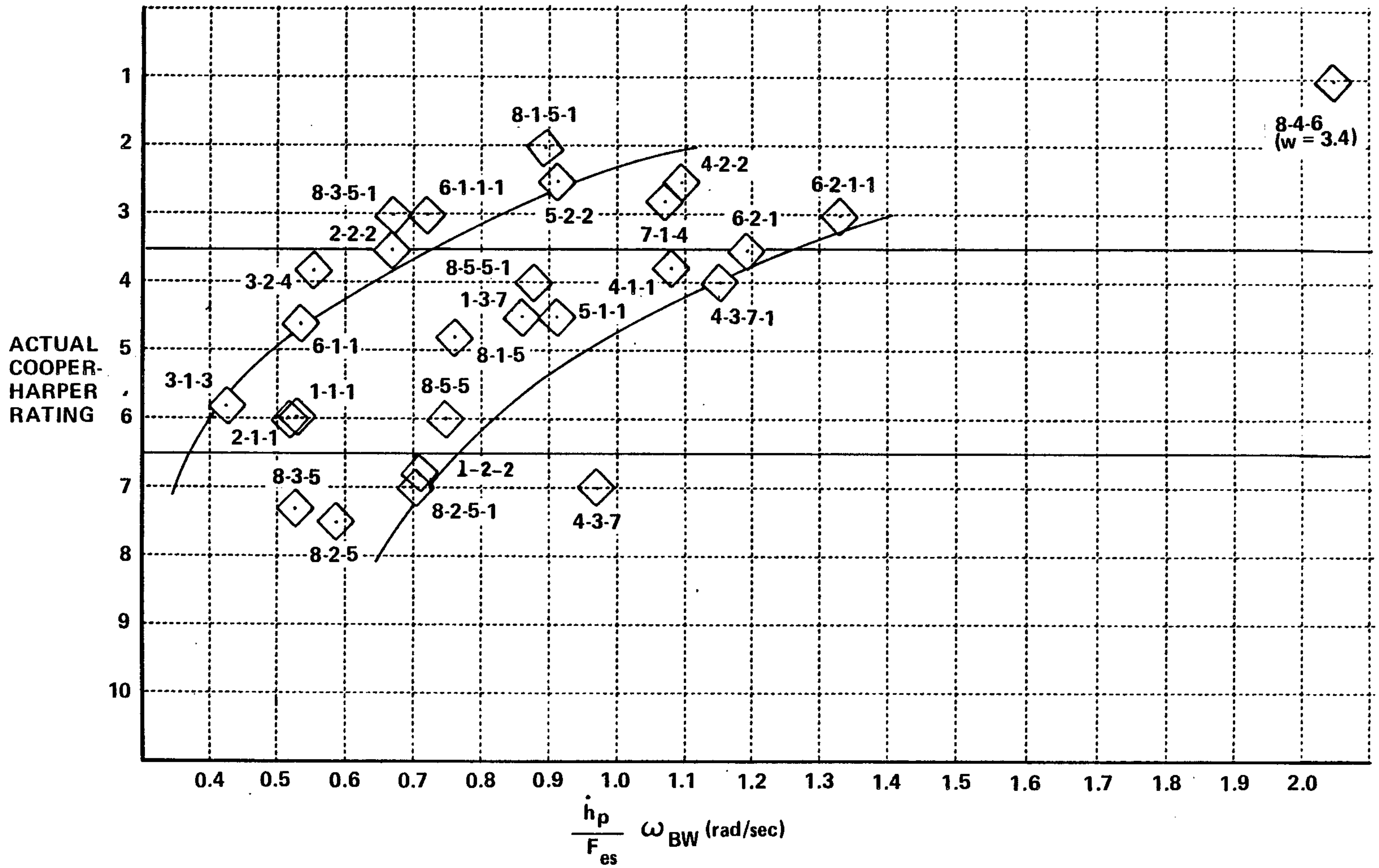


Figure 45 COMPARISON OF $\dot{h}_p/F_{es}$ BANDWIDTH AND ACTUAL PILOT RATINGS

and the prefilter configurations consistently received Level 1 and upper Level 2 ratings. The shuttle configuration with the canard (Configuration 8-4-6) received a Cooper-Harper rating of 1 and had the highest altitude-rate bandwidth (ω_{BW} = 3.4 rad/sec). The command washout filter did not increase the altitude-rate bandwidth to the extent of the improvements in the pilot ratings. The altitude-rate bandwidth does not explain the effects of the washout filter on the pilot's technique and the pilot ratings.

The pilot comments associated with altitude-rate control are fairly consistent with the increase in altitude-rate bandwidth. Figure 46 displays typical pilot comments relating to altitude-rate control associated with the points in Figure 45. The higher bandwidth configurations were basically said to have good altitude-rate control and predictability, whereas the lower bandwidth configurations experienced difficulties in this area. Based on the relationship in Figure 45, a tentative set of handling qualities boundaries were formulated:

$\omega_{BW} \geq 0.9$ Level 1

$\omega_{BW} \geq 0.7$ Level 2

$\omega_{BW} \leq 0.7$ Level 3

It must be stated that these boundaries are based on a trend derived from a single set of data for the sole purpose of making a prediction of the handling qualities ratings for the configurations. Predicted pilot ratings for the configurations were made through linear interpolation from Figure 45 and using the level boundaries stated above. With this in mind, Figure 47 shows a comparison of predicted pilot ratings based on altitude-rate bandwidths and the actual pilot ratings. Despite the possible error in the predicted pilot ratings, a majority of the configurations were predicted within one pilot rating of the actual value. The altitude-rate bandwidth does appear to be a dominating parameter in the pilot's task during a landing task.

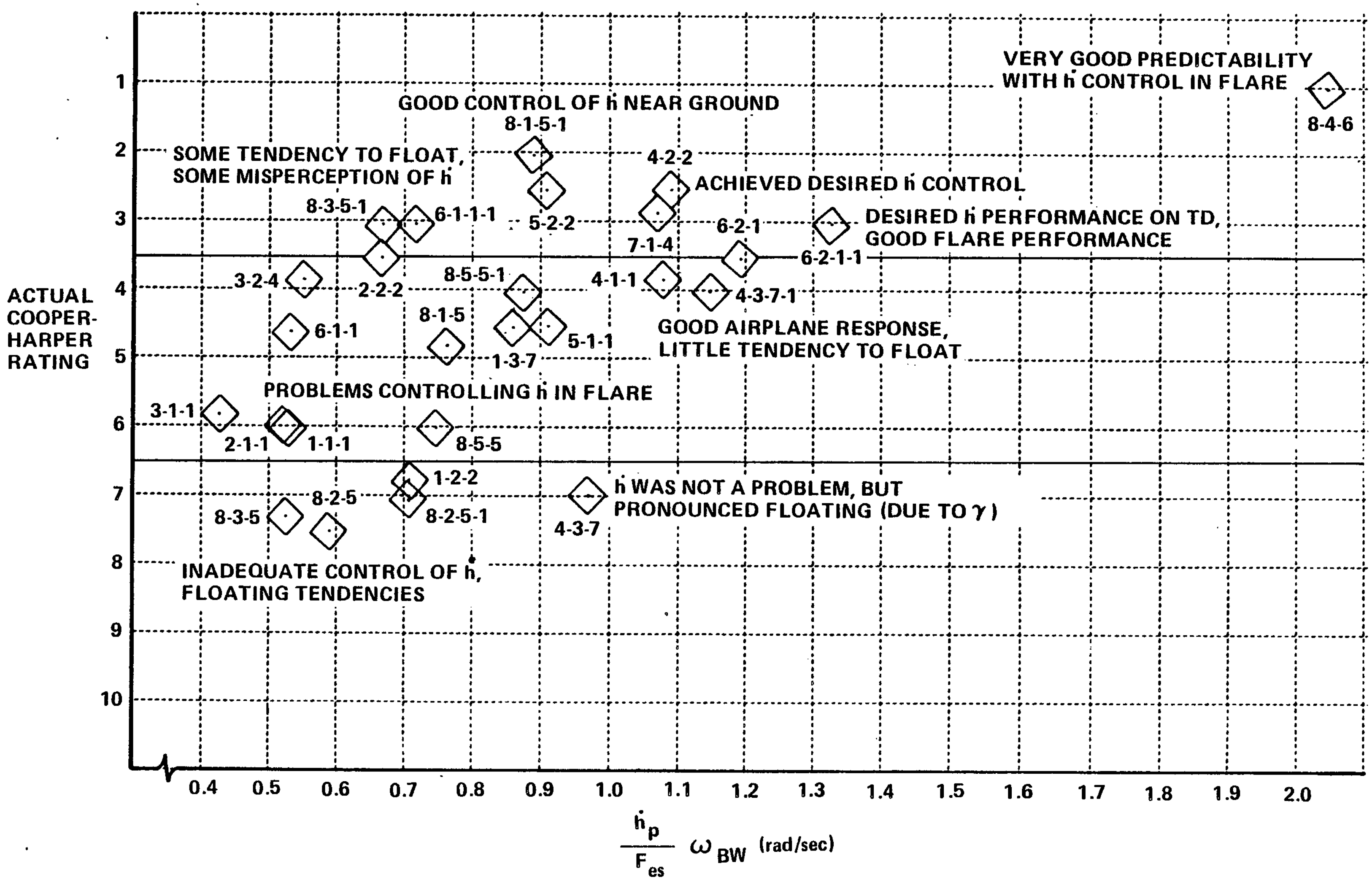


Figure 46 PILOT COMMENTS REGARDING ALTITUDE RATE CONTROL

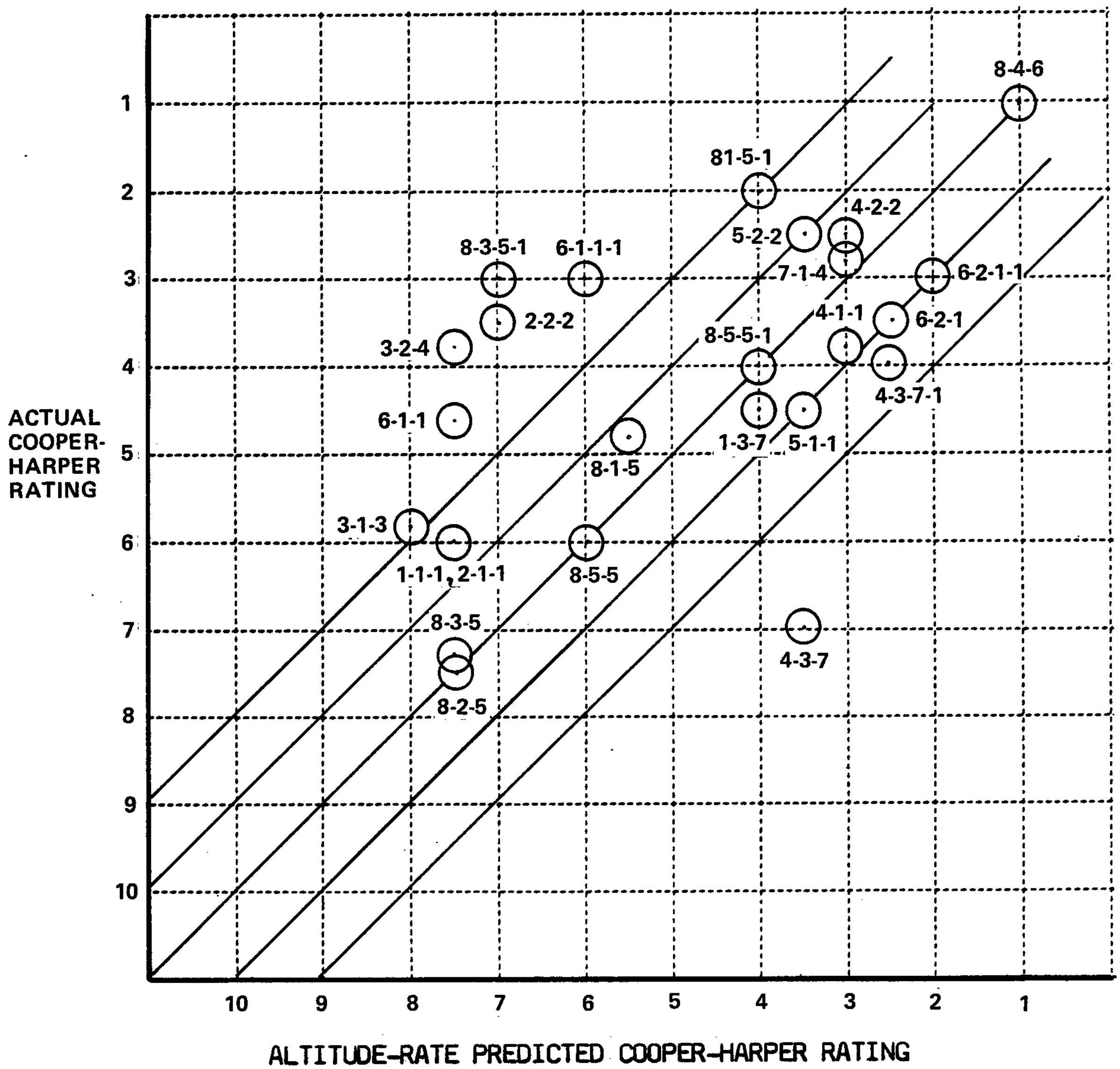


Figure 47 COMPARISON OF ACTUAL PILOT RATINGS AND ALTITUDE-RATE PREDICTED PILOT RATINGS

4.2.3.2 Time Domain Analysis

The time domain analysis did not begin as such, but as a preliminary study of the time histories of each configuration (Appendix A) in an attempt to correlate them with pilot ratings. The time histories were a response to an elevator step IN, step OUT, i.e., a pulse of five seconds duration. This input was chosen in order to facilitate curve matching during inflight configuration verification.

- **Effect of Lead/Lag Pre-Filter**

The effect of the lead/lag pre-filter was apparent in the time histories as increase of pitch rate overshoot, increase in angle of attack (α) frequency i.e., time to first peak, and an increase in the initial acceleration at the pilot station (N_{z_p}). A comparison of time histories (Appendix A) of configurations 1-1-1 (no pre-filter, average HQR = 6), 4-1-1 (1-1-1 with a lead/lag pre-filter, average HQR = 3.8), and 7-1-4 (conventional aircraft, average HQR = 2.8), will show these trends.

- **Definition of Alpha Time History Terms**

As the time domain criteria developed it became apparent that the alpha time history of the "conventional aircraft", configuration 7-1-4, displayed characteristics that were desired for Level 1 performance. One desired characteristic is an alpha "quickness", or time to first peak, that results from the $1/\tau_{\theta_2}$ zero location, pitch rate overshoot etc. The second characteristic is the flatness of the alpha time history subsequent to the short period response of the step input, or the constant alpha steady state response to the step input. This "flatness" of the alpha response is due to the phugoid roots, "phugoid like" roots (washout pre-filter), static stability etc. and provides the speed stability characteristic of "conventional" statically stable aircraft. The "flatness" characteristic is described in this report as "alpha command" to differentiate it from the "pitch rate command" characteristic of integrated pitch rate feedback flight control systems. The term "alpha command" is not meant to infer an alpha loop closure by the pilot any more than the term "pitch rate command" infers a pitch rate loop closure. An important by-product of "flatness of the alpha response", "alpha command",

"speed stability", etc. is that it allows monotonic stick forces in the landing flare. The pitch forces are monotonic in that the flare requires modulation of aft stick pressure rather than reversal of stick forces in the landing flare as required by pitch rate flight control systems.

- **Effect of Washout Pre-Filter**

The primary effect of the washout filter as observed on the time histories was to bend the alpha curve down such that it resembles a pure alpha command system similar to the conventional aircraft configuration. A comparison of configurations 6-1-1-1 (superaugmented, HQR = 3.0), and 7-1-4 (the conventional aircraft, average HQR = 2.8), in Appendix A demonstrates this effect. It begins to appear to the observer, at this point, that a way to make a flight control system produce good landing characteristics might be to design it such that the time histories look like those of conventional aircraft i.e., classical well behaved short period and phugoid.

- **Effects of Combining Lead/Lag and Washout Pre-Filters**

A study of time histories of 6-1-1 (superaugmented, average HQR = 5.0), 6-2-1 (6-1-1 with lead/lag prefilter, HQR = 3.7), and 6-2-1-1 (6-2-1 with a washout pre-filter, HQR = 3.0) demonstrates the progression of a typical pitch rate command system as the $1/\tau_{\theta_2}$ zero is restored, and alpha frequency improved (lead/lag pre-filter), and alpha command is restored (monotonic stick forces in the landing flare due to the washout filter). All these manipulations tend to make the time history become more like that of 7-1-4 the "conventional" Level 1 aircraft.

- **Effect of Vertical Acceleration at the Pilot Station (N_{z_p})**

Configuration 8-4-6 (shuttle like canard, HQR = 1) was initially a paradox to the analysis. The basis of this configuration was 8-3-5 (shuttle like OFT, Average HQR = 6.7) a Level 2/3 configuration. It was converted to a canard configuration by changing the sign of L_{δ_e}. The pitch rate and alpha curves are quite similar to those of 8-3-5, however, the N_{z_p} curve is noticeably different. The initial N_{z_p} is slightly higher than steady state. This observation tended to enforce the belief that vertical acceleration at the

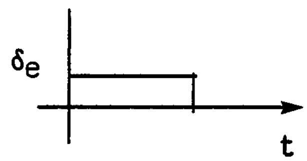
pilot station is another important factor in pilot ratings in the landing task (the lack of time delay in the γ response, due to L_{δ_e} contribution, of this configuration was also a strong factor in the pilot rating).

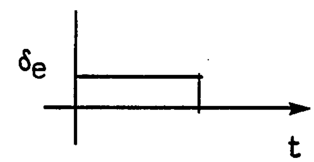
4.2.3.3 Identification of Time Domain Parameters

From a piloting standpoint the physical aspects of the improvements seen as a result of the pre-filter were more obvious than was an analytical criterion based on time history measurements. The lead/lag pre-filter obviously quickened the alpha response thus allowing the aircraft to follow the inputs of the pilot more quickly and produce better flight path (γ) response. Additionally, the initial vertical acceleration at the pilot station was increased thus giving the pilot a preliminary cue that he had made an input in the proper direction and also an indication of the magnitude of that input (which would eventually change γ). The washout prefilter provided more nearly an angle of attack command that restored monotonic control forces in the flare i.e., the force on the stick was an indication of the alpha change commanded (eventual γ change) and the pilot could conduct the flare without reversing stick forces i.e., no requirement to "push to land". It is desirable that the alpha response be "flat" (i.e., proportional to stick deflection) after the short period transient because the pilot can use the stick force cue as an indication of angle of attack and, because alpha tends to stay constant, the attitude-rate equals the flight path rate. The pilot thus has two observable cues (i.e., stick feel and pitch attitude change) that are useful in controlling flight path. In the case of the rate command system, the angle of attack and the flight path both vary continuously following a stick command and the pilot cannot evaluate how much either one is varying by observing the pitch attitude. The stick deflection and pitch attitude only give information about pitch attitude not alpha or gamma. It is desirable for the alpha response to be proportional to stick commands not because the pilot observes alpha and controls it directly but rather because when the alpha response is proportional to stick commands the pilot can use stick force to predict flight path.

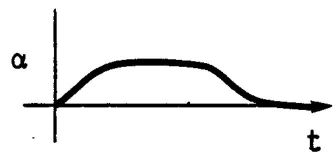
Continued study of the time histories began to provide a visual correlation of time history shapes with pilot ratings. Two basic curve parameters appeared to correlate with better ratings.

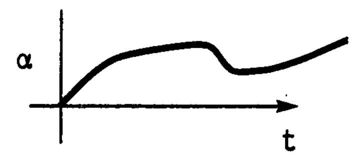
a. The "flatness" of the alpha curve in the steady state



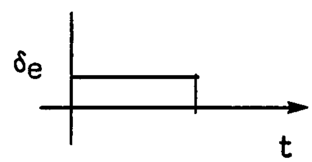


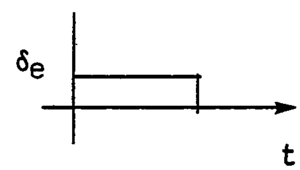
this   rather than this



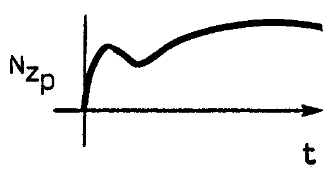


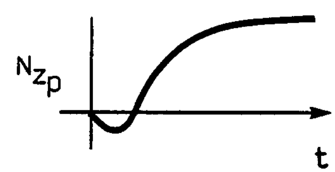
b. The initial acceleration of the pilot station





this   rather than this

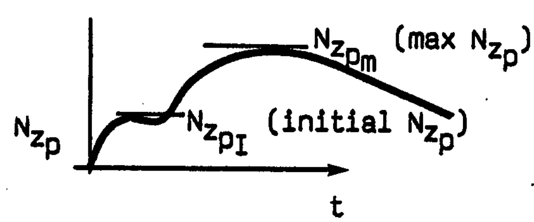




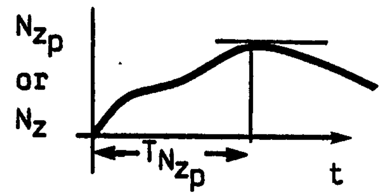
It became obvious that if one could identify the "goodness" of the time history shapes in a numerical manner a method of predicting pilot rating from time history parameters might be feasible.

The following are some of the preliminary time domain parameters tested for correlation with flight results:

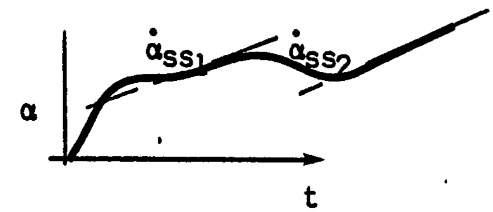
1. $N_{z_{p_I}}/N_{z_{p_m}} = N'_{z_p}$



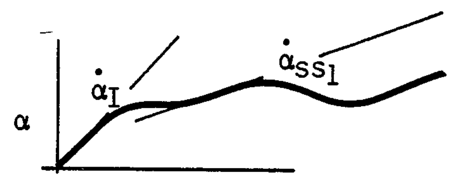
2. $T_{N_{z_p}}$



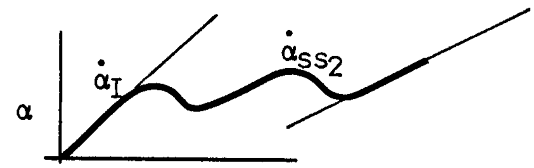
3. $\dot{\alpha}_{ss_1}/\dot{\alpha}_{ss_2}$



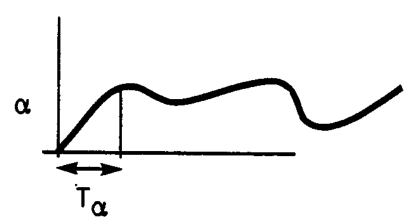
4. $\dot{\alpha}_{ss_1}/\dot{\alpha}_I = \dot{\alpha}'$



5. $\dot{\alpha}_{ss_2}/\dot{\alpha}_I$

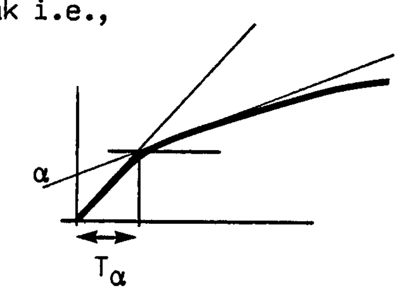


6. T_α

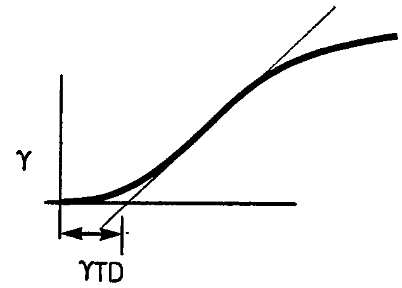


Note: this was later modified to accomodate α curves with no definite peak i.e.,

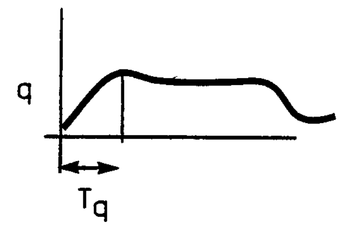
6a. T_α



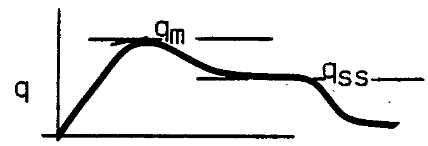
7. γ Time Delay



8. T_q



9. q_m/q_{ss}



10. $T_q - T_\alpha$

All these parameters were plotted versus flight HQR's for possible correlation. None of the correlations were significant enough to justify other than linear relationships. Manual manipulation of various combinations of parameters

showed some promising correlations. The parameter combination showing best correlations were $N_{z_{p_I}}/N_{z_{p_m}} \equiv (N'_{z_p})$ and $\dot{\alpha}_{ss_1}/\dot{\alpha}_I \equiv (\dot{\alpha}')$. When these parameters were plotted individually, however, no direct correlation was apparent (Figures 48 and 49).

4.2.3.4 Development of Time Domain Predictive Criteria

A least squares fit computer program was used in an attempt to further identify the significant parameters of those listed above. The results of this effort showed significant correlation with only $(\dot{\alpha}')$ and (N'_{z_p}), and provided the following relationship:

$$\text{Predicted HQR (PHQR)}_1 = 3.6\,\dot{\alpha}' - 2.0\,N_{z_p} + 4.3$$

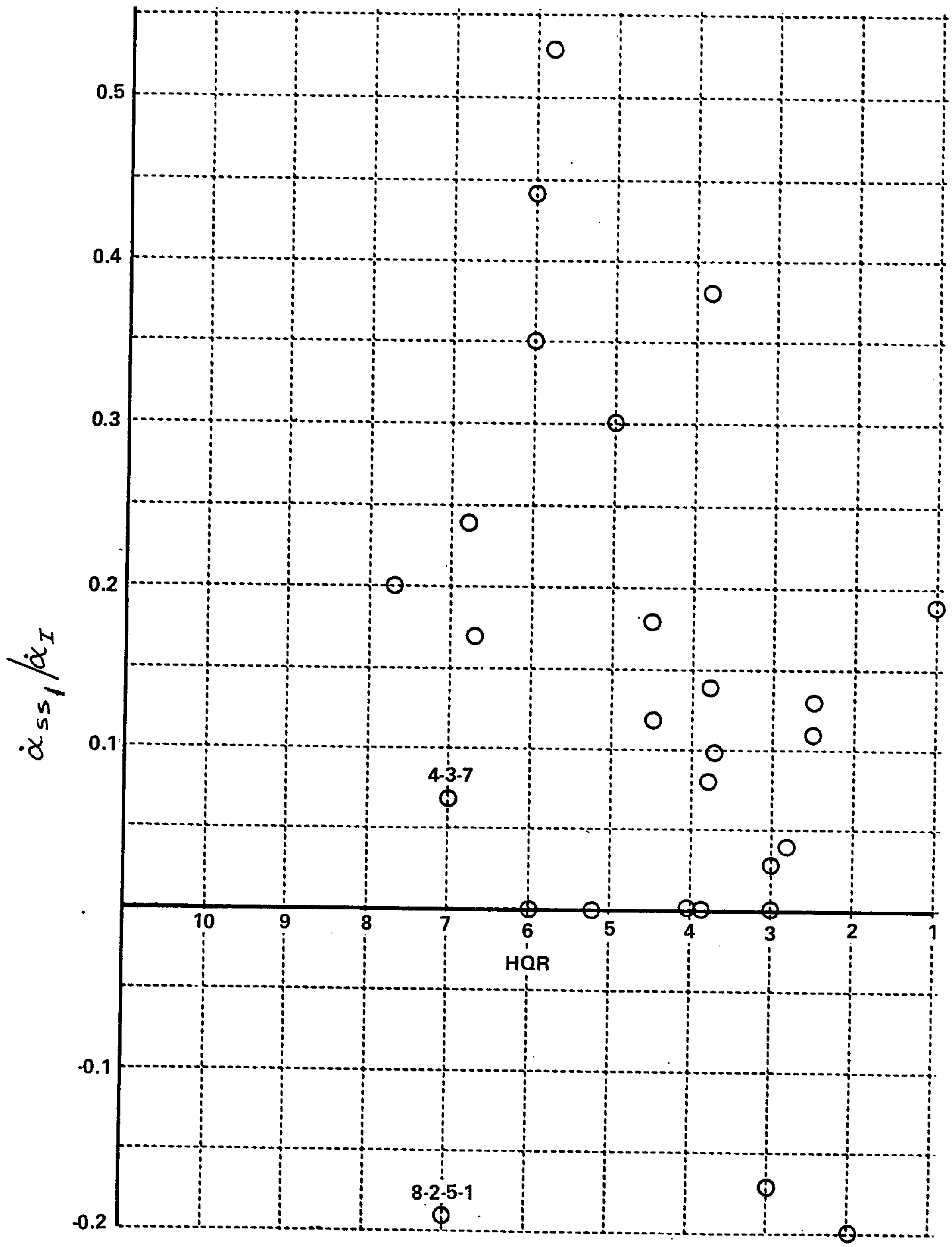


Figure 48 CORRELATION OF $\dot{\alpha}$ PARAMETER

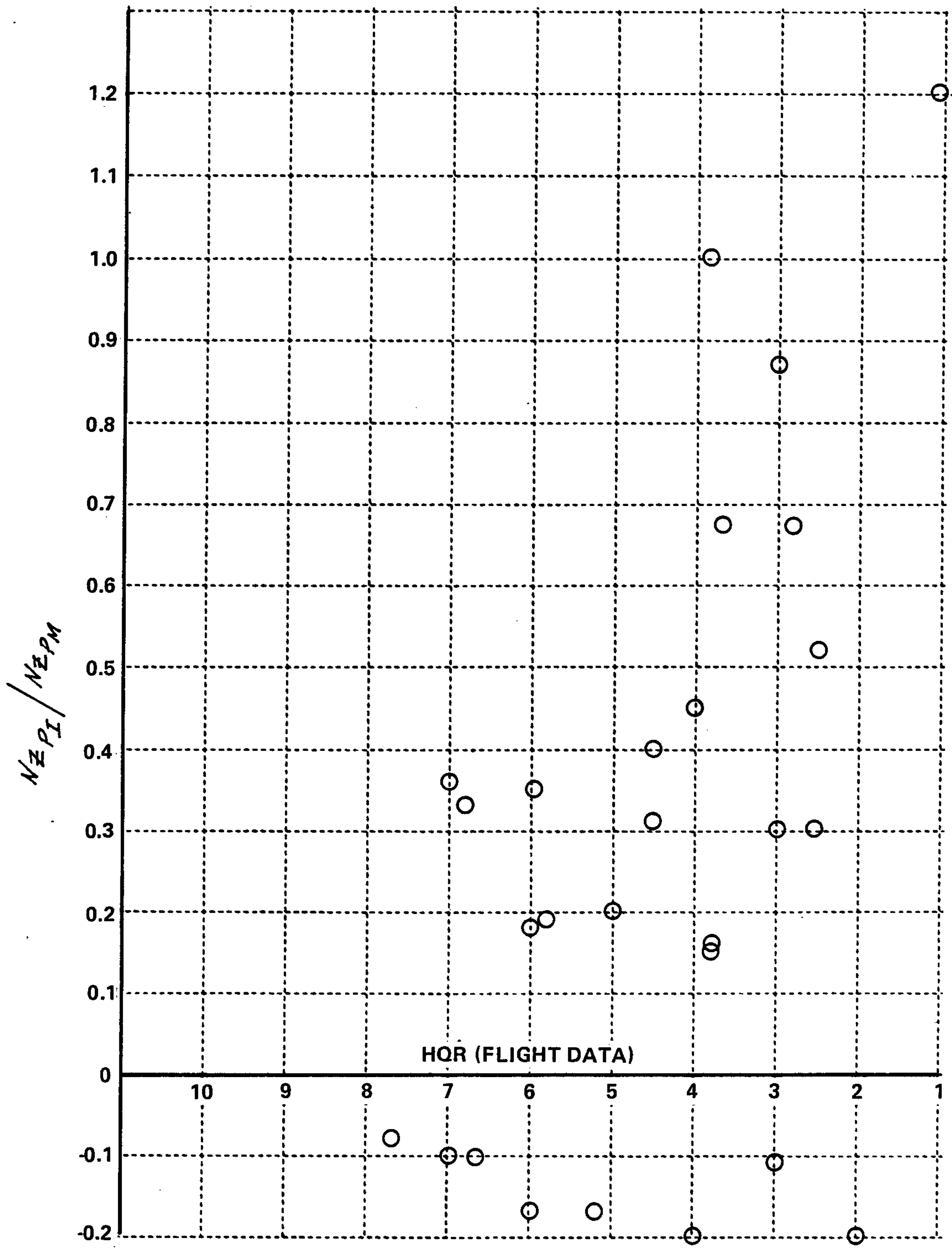


Figure 49 CORRELATION OF Nz_p PARAMETER

A comparison of this algorithm with flight data is shown in Table 2 of Appendix K and on Figure 50. This relationship provided the following predictive accuracy (configurations 4-3-7 and 8-2-5-1 were not used in the data base and are excluded for comparison purposes, however, they are shown on the curves).

15 of 25 (60%) $PHQR_1$ - HQR $< \pm 1$
7 of 25 (32%) $PHQR_1$ - HQR $\pm 1 < \pm 2$
and 2 of 25 (8%) $PHQR_1$ - HQR $> \pm 2$
or 92% were predicted within less than 2 HQR numbers

A limitation of this predictive method, however, was that it did not account for effects of frequency. The configurations tested in this flight program were all chosen from within the MIL 8785 boundaries for Level 1 performance and there was not sufficient variation to identify significant frequency related parameters. This shortcoming became readily apparent when the time domain criteria was applied to another data base, the Large Aircraft data of Reference 4. (The Large Aircraft program task was an instrument approach to a simulated landing. The ratings were not broken down into the two phases of the task and some ratings were based on the instrument approach, these were discarded. Also discarded were those configurations with time delays in excess of those used for the Pitch Rate Program).

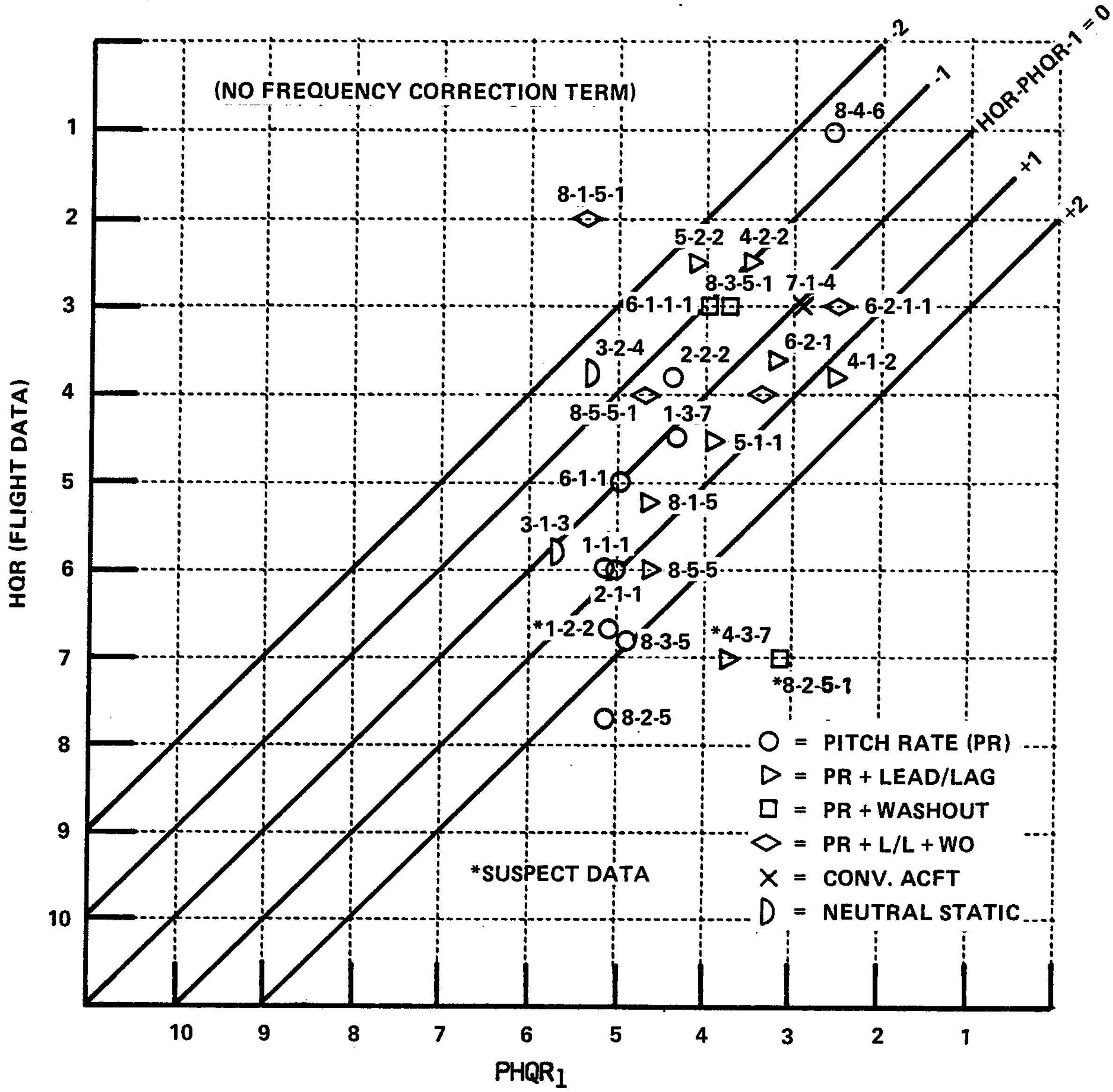
4.2.3.5 Application of Original Time Domain Criteria to Large Aircraft Data

Figure 51 is a plot of the data from the Large Aircraft Program, the supporting data is shown in Table 3 of Appendix K.

The correlations of Figure 51 showed:

6 of 16 (38%) $PHQR_1$ - HQR $< \pm 1$
7 of 16 (43%) $PHQR_1$ - HQR $\pm 1 < \pm 2$
and 3 of 16 (19%) $PHQR_1$ - HQR $> \pm 2$
or 81% were predicted within less than 2 HQR numbers

These figures look acceptable on the surface, however, four strong Level 3 configurations, (HQR's = 9, 9, 9 and 10) were not identified as such. For a valid predictive criteria this was considered unacceptable.

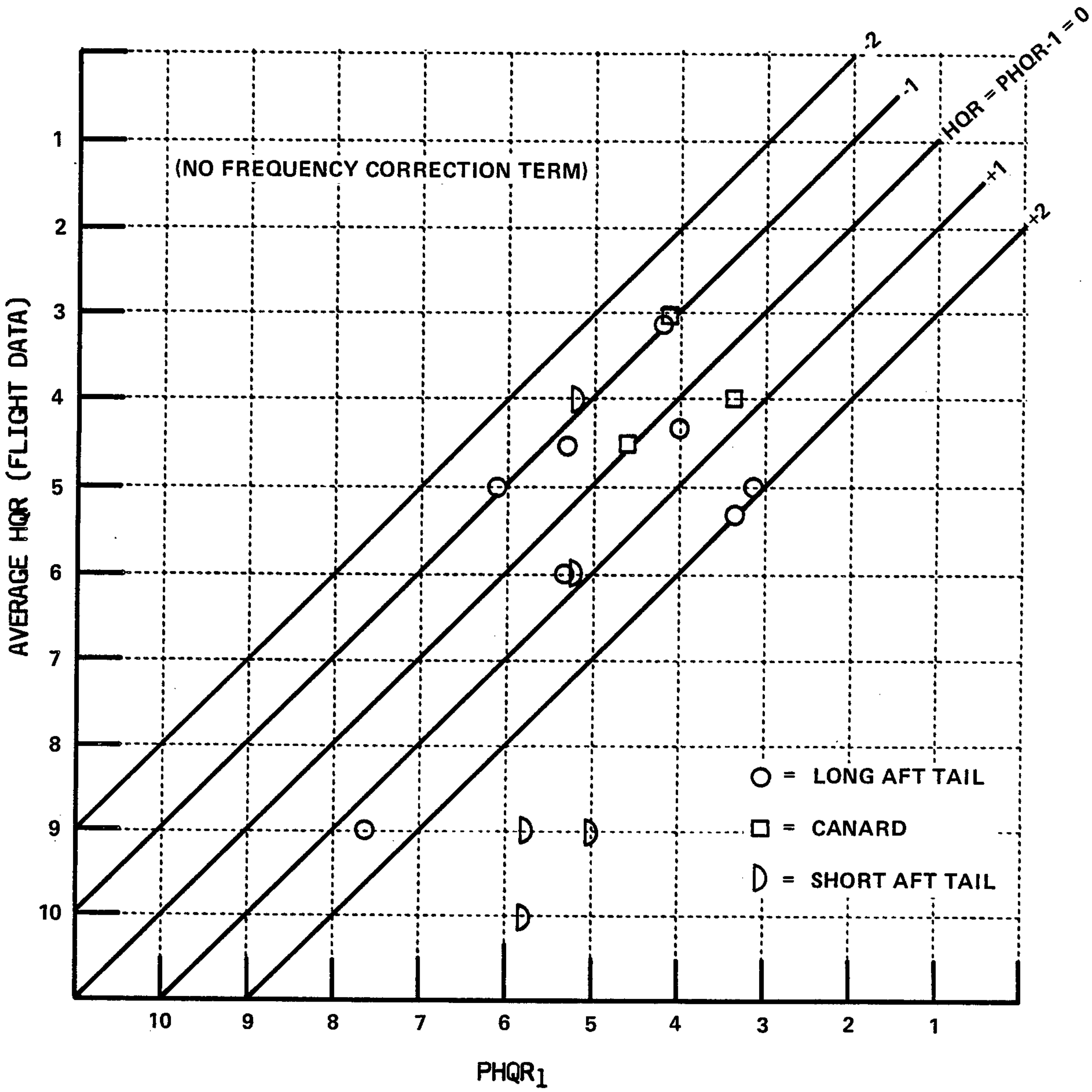


$$PHQR_1 = 3.6\,\dot{\alpha}' - 2.0\,N'_{z_p} + 4.3$$

WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I \,, \quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

Figure 50 PREDICTED HQR (PHQR) VS FLIGHT HQR (HQR) (FINAL APPROACH AND FLARED LANDING) PITCH RATE PROGRAM (1983)



$$PHQR_1 = 3.6\,\dot{\alpha} - 2.0\,N_{z_p} + 4.3$$

WHERE:

$$\dot{\alpha} = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\,, \quad N_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

Figure 51 PREDICTED HQR (PHQR) VS FLIGHT HQR (HQR) (INSTRUMENT APPROACH TO SIMULATED FLARED TOUCHDOWN) LARGE AIRCRAFT PROGRAM (1981)

4.2.3.6 Development of a Frequency Related Parameter for the Time Domain Criteria

Previous attempts at correlating any of the frequency related parameters, T_α, T_q, and T_{N_Z} had shown very weak correlations. As was the case in the previous development, an approach was arrived at by first determining what was happening to the pilot in a physical sense and then developing an analytical criteria to determine the efficiency of the physically derived hypothesis.

In this case one must consider what a pilot requires as regards sensory feedback, in order to execute a flared landing in an aircraft. He must obviously control flight path (γ) and his primary sense of flight path is altitude-rate ($\dot{h}$). The $\dot{h}$ loop is rather slow, however, and fortunately the pilot normally has other, and faster, "surrogate" cues to assist him in controlling $\dot{h}$ in the landing flare. First, if the flight control system provides alpha command i.e., a conventional aircraft, the stick force applied is proportional to the angle of attack (α) commanded and the rate of change of flight path is proportional to (α). In short, the force applied to the stick is an indication to the pilot of the rate of change of flight path he has commanded. He doesn't have to wait for $\dot{h}$ to change in order to initially judge his input size . Second, if the pilot is provided cockpit acceleration cues, this feedback (in many cases subconscious) will also provide a preliminary indication of the eventual result of his input i.e., flight path change.

If the pilot is denied both of these "surrogate" cues he is forced to close the $\dot{h}$ loop using $\dot{h}$ as the only feedback and becomes very dependent on the frequency of the alpha (α) response (the mechanism for flight path change). If this response is slow, either due to a short period frequency out of the Level 1 specification boundary or a slow alpha response because of control system design, the pilot will have much difficulty in closing the $\dot{h}$ loop and a poor rating will result. (A significant result of this flight experiment was the indication that both "surrogate" cues are not necessary. Either one, if sufficiently strong, can provide Level 1 ratings).

Previous attempts to correlate the alpha frequency (T_α) with ratings were unsuccessful because T_α only becomes a significant factor if the

"surrogate" cues i.e., monotonic stick forces, or cockpit acceleration cues are missing. (T_α was applied to the least squares fit program and poor correlation resulted, even in combination with other significant parameters. Figure 52 is a plot of T_α with HQR and shows the lack of direct correlation of this term alone).

Consequently, a parameter was developed that allowed stronger contribution of the alpha frequency when the stick force and acceleration cues were reduced. The parameter is "weighted T_α" (or T_α') where:

$$T'_\alpha = |T_\alpha - 1| \left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05} \right]$$

and

when $T'_\alpha > 6$ let $T_\alpha = 6$

(The 0.05 terms prevent un-realistic contributions of T_α when $\dot{\alpha}'$ or N'_{z_p} are very small or zero. The (T_α - 1) term indicates that T_α = 1 sec is a near optimum value for flared landing task.

A plot of T'_α versus HQR is shown on Figure 53 and shows some improvement in direct correlation than T_α unweighted. A similar term was developed for T_{N_z} and the two along with the previous parameters ($\dot{\alpha}'$) and (N'_{z_p}) were applied to the pitch rate data and put in the least squares fit program to determine correlation effectiveness. The result was that the weighted T_α parameter (T'_α) showed significant correlation along with $\dot{\alpha}'$ and N'_{z_p}. The weighted T_{n_z} parameter displayed no significant correlation.

> It should be noted at this point that in all cases only the pitch rate data base was used in the development of the time domain criteria. The criteria algorithms were then applied to other flight data as a check for more general application.

The relationship resulting from the least squares fit program was:

$$PHQR = 1.7\ (\dot{\alpha}') - 1.44\ (N'_{z_p}) + 0.55\ T'_\alpha + 3.9$$

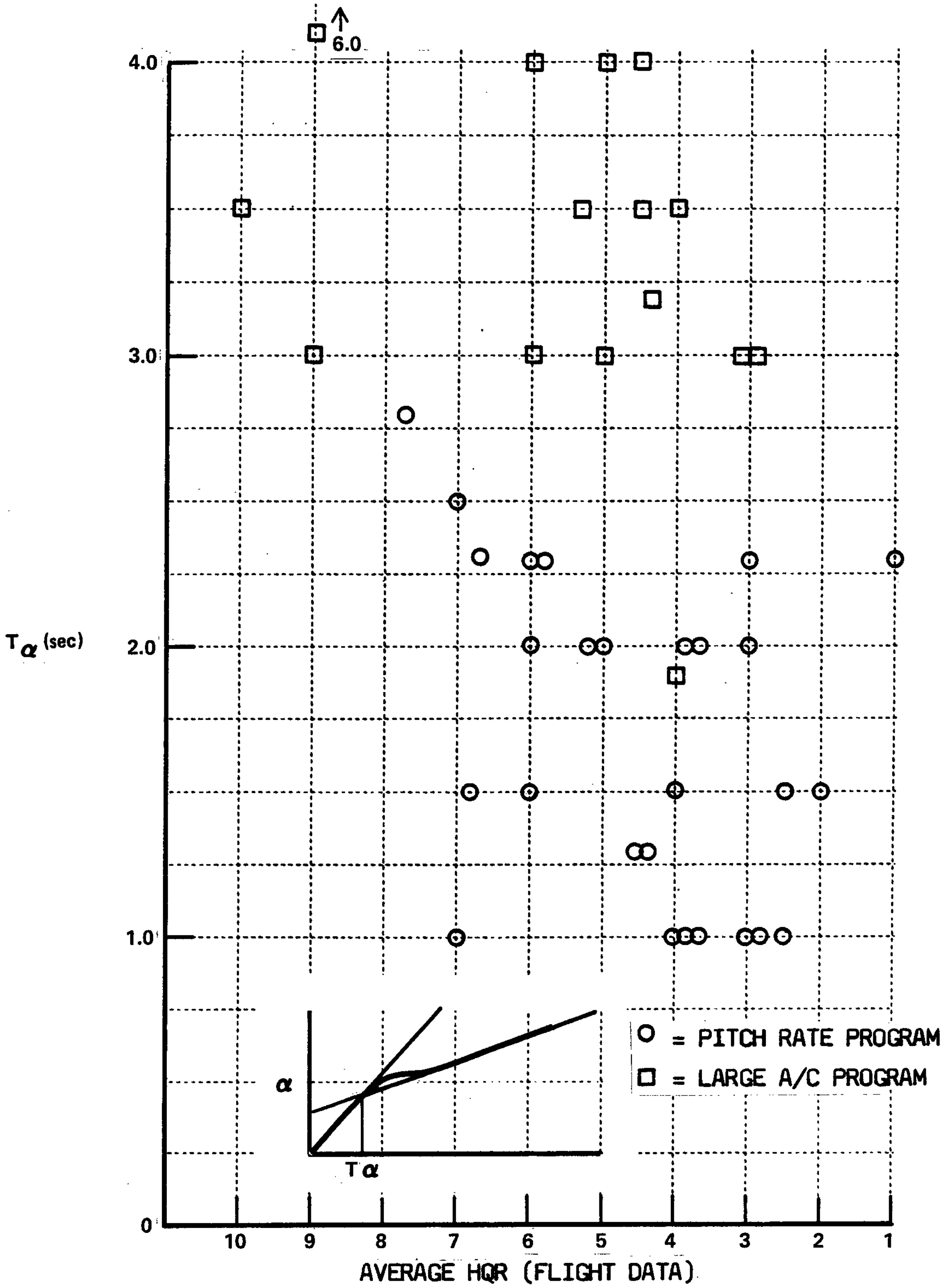
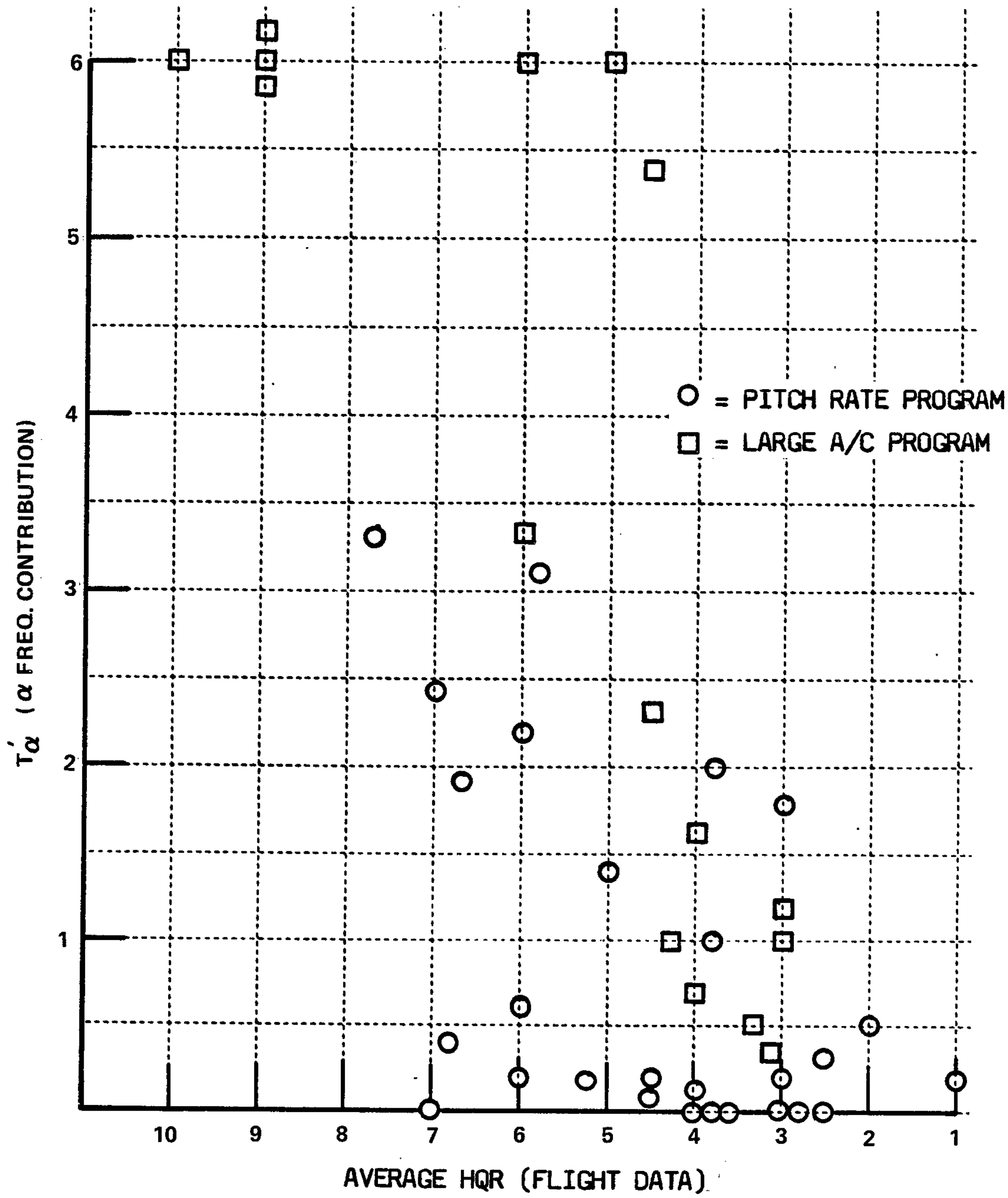


Figure 52 CORRELATION OF T_α PARAMETER (WHERE T_α = TIME TO INTERSECTION OF INITIAL AND STEADY STATE SLOPES OF α RESPONSE TO STEP)



WHERE:

$$T'_\alpha = \left[\left| T\alpha - 1 \right| \left(\frac{\left| \dot{\alpha}' \right| + 0.05}{\left| Nz'_p \right| + 0.05} \right) \right]$$

(FOR $T'_\alpha > 6$, LET $T'_\alpha = 6.0$)

Figure 53 CORRELATION OF WEIGHTED T_α TERM (T'_α)

4.2.3.7 Application of the Frequency Corrected Time Domain Criteria to the Pitch Rate Data Base

Figure 54 is a comparison plot of the above relationship applied to the pitch rate data, and Table 2 of Appendix K lists the supporting data. The correlations of the pitch rate data were:

14 of 25 (56%) PHQR - HQR < ±1
9 of 25 (36%) PHQR - HQR ±1 < ±2
2 of 25 (8%) PHQR - HQR > ±2
or 92% were predicted to within less than 2 HQR numbers

4.2.3.8 Application of Frequency Corrected Time Domain Criteria to the Large Aircraft Data

The relationship:

$$PHQR = 1.7\ (\dot{\alpha}') - 1.44\ (N'_{z_p}) + 0.55\ T'_{\alpha} + 3.9$$

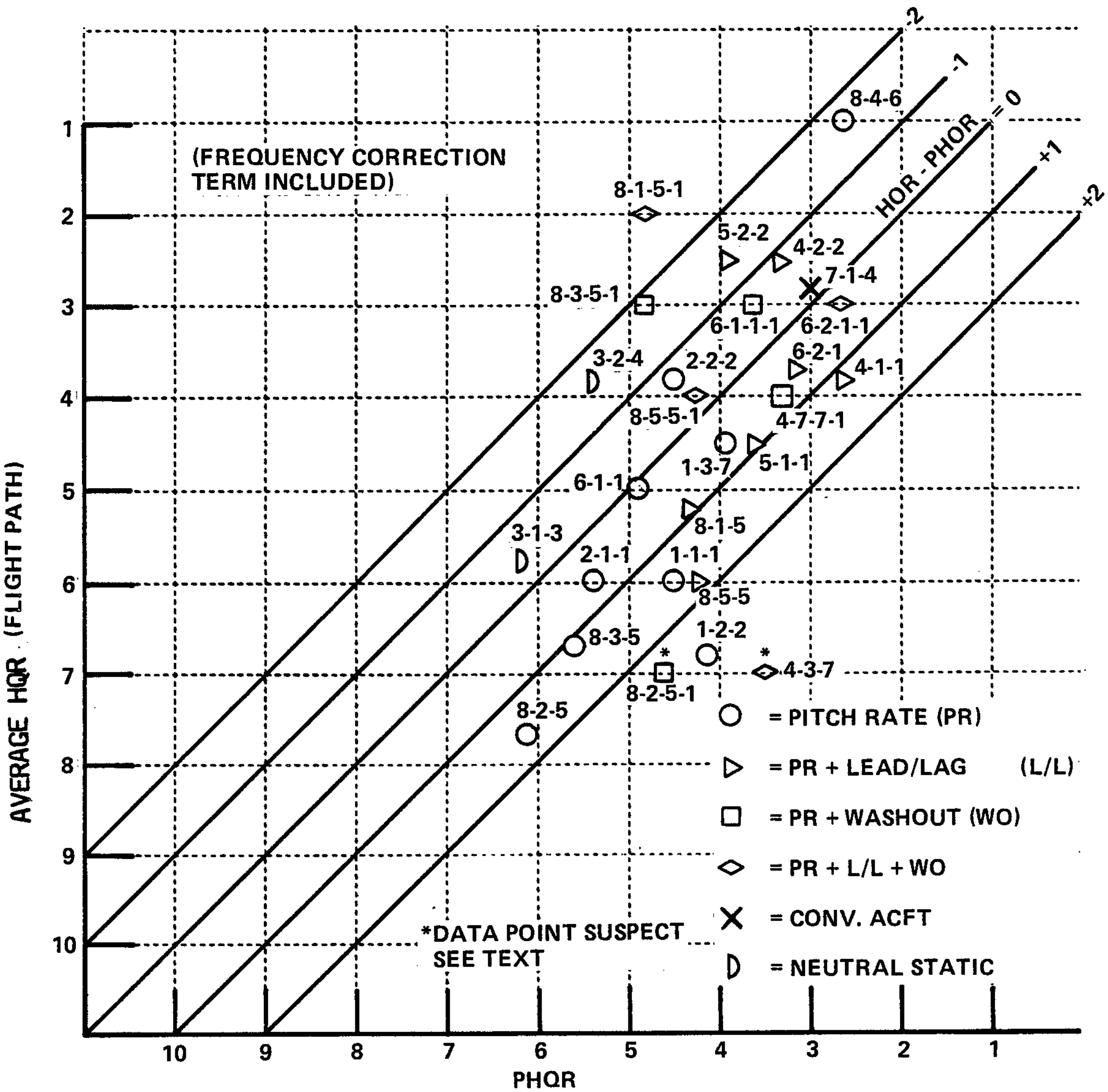
was applied to the large aircraft data and the results are plotted on Figure 55 with supporting data in Table 3 of Appendix K. These correlations showed:

5 of 16 (31%) PHQR - HQR < ±1
8 of 16 (50%) PHQR - HQR ±1 < ±2
3 of 16 (19%) PHQR - HQR > ±2
or 81% within less than ±2 HQR numbers

These results are similar numerically to the non-frequency corrected results but the significant difference is that all Level 3 configurations are properly identified.

4.2.3.9 Application of Frequency Corrected Time Domain Criteria to SST Data

The SST program (Reference 13) provided an additional check of the application of the time domain criteria. All but three of the SST configurations were unstable and divergent to a step input. The time domain criteria will not apply to divergent time histories because there is no steady



$$PHQR = 1.7\,\dot{\alpha}' - 1.44\,N'_{z_p} + 0.55\,T'_{\alpha} + 3.9$$

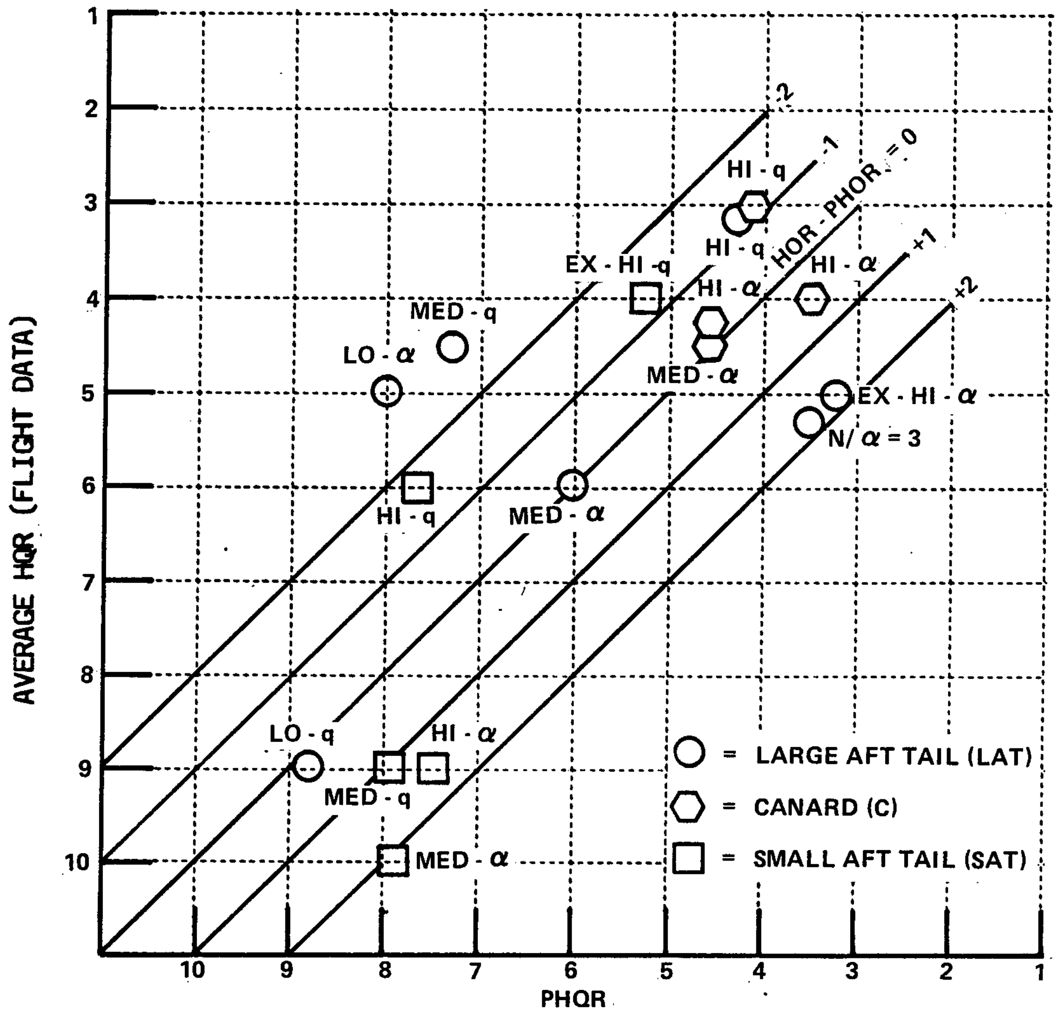
WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\ , \quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

$$T'_{\alpha} = |T_{\alpha} - 1|\left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05}\right]$$

(for $T'_{\alpha} > 6$, let $T'_{\alpha} = 6.0$)

Figure 54 PREDICTED HQR (PHQR) VS. FLIGHT HQR (HQR) FINAL APPROACH AND FLARED LANDING) PITCH RATE PROGRAM (1983)



$$PHQR = 1.7\,\dot{\alpha}' - 1.44\,N'_{z_p} + 0.55\,T'_{\alpha} + 3.9$$

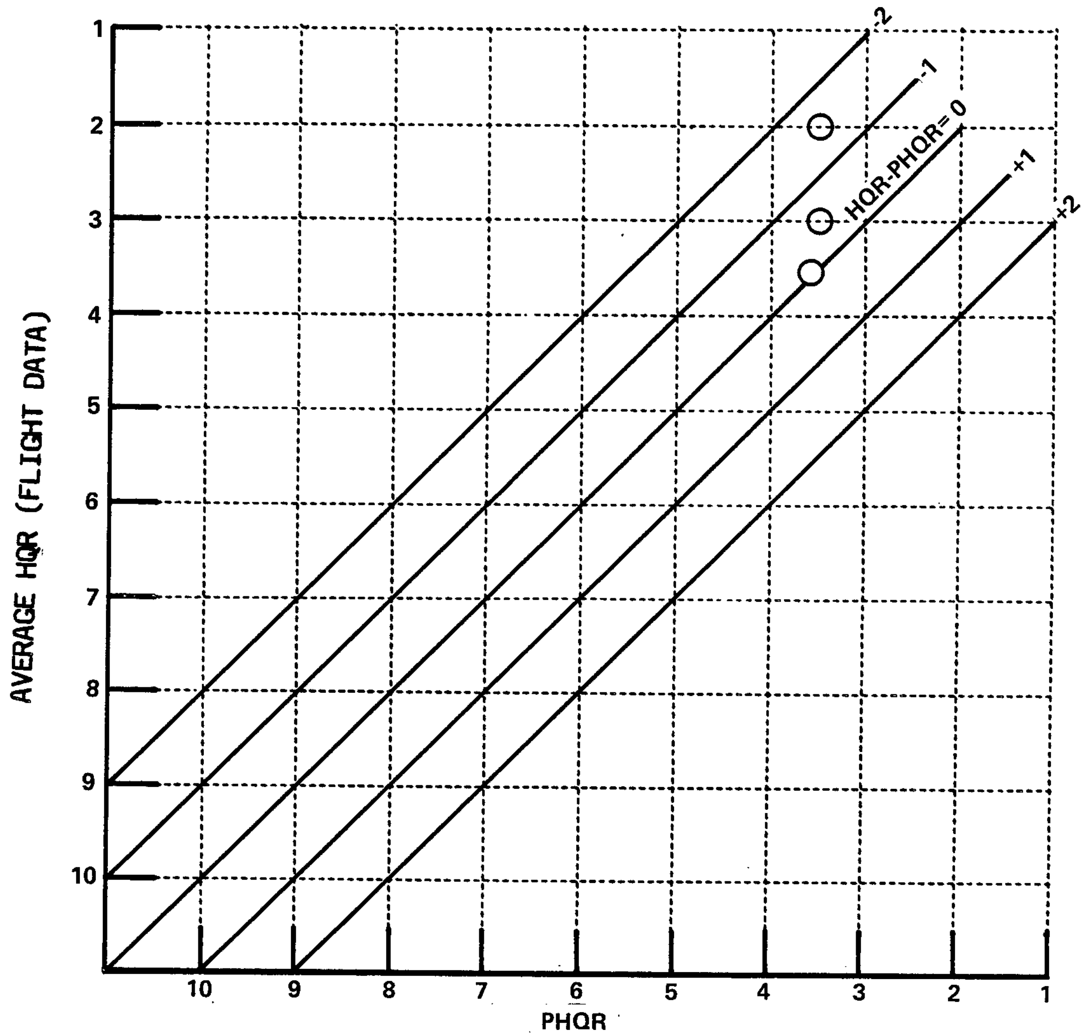
WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\ , \quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

$$T'_{\alpha} = |T_{\alpha} - 1| \left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05}\right]$$

(for $T'_{\alpha} > 6$, let $T'_{\alpha} = 6.0$)

Figure 55 PREDICTED HQR (PHQR) VS. FLIGHT HQR (HQR) (FLARED LANDINGS, SIMULATED TOUCHDOWN) LARGE AIRCRAFT PROGRAM (1981)



$$PHQR = 1.7\,\dot{\alpha}' - 1.44\,N'_{z_p} + 0.55\,T'_{\alpha} + 3.9$$

WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I \,, \quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

$$T'_{\alpha} = |T_{\alpha} - 1| \left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05} \right]$$

(for $T'_{\alpha} > 6$, let $T'_{\alpha} = 6.0$)

Figure 56 PREDICTED HQR (PHQR) VS. FLIGHT HQR (HQR)$^{-2}$ (FINAL APPROACH AND FLARED LANDING) SST PROGRAM DATA (1972)

state angle of attack. Consequently, only the three stable SST configurations were tested with the time domain criteria and the results are shown in Table 4 of Appendix K and Figure 56. As Figure 56 displays, two of the three configurations were predicted within one HQR and the third within 1.5 HQR.

As the SST configuations tested were at near optimum frequency these points are not a good test of the time domain frequency parameter.

4.2.3.10 Correlation of Time Domain Criteria With All Data Bases Tested

Figure 57 is an overlay of all comparison figures. The numerical results are:

21 of 44 (48%) PHQR - HQR $< \pm 1$
18 of 44 (41%) PHQR - HQR $\pm 1 < \pm 2$
5 of 44 (11%) PHQR - HQR $> \pm 2$
or 89% were predicted to within less than 2 HQR numbers

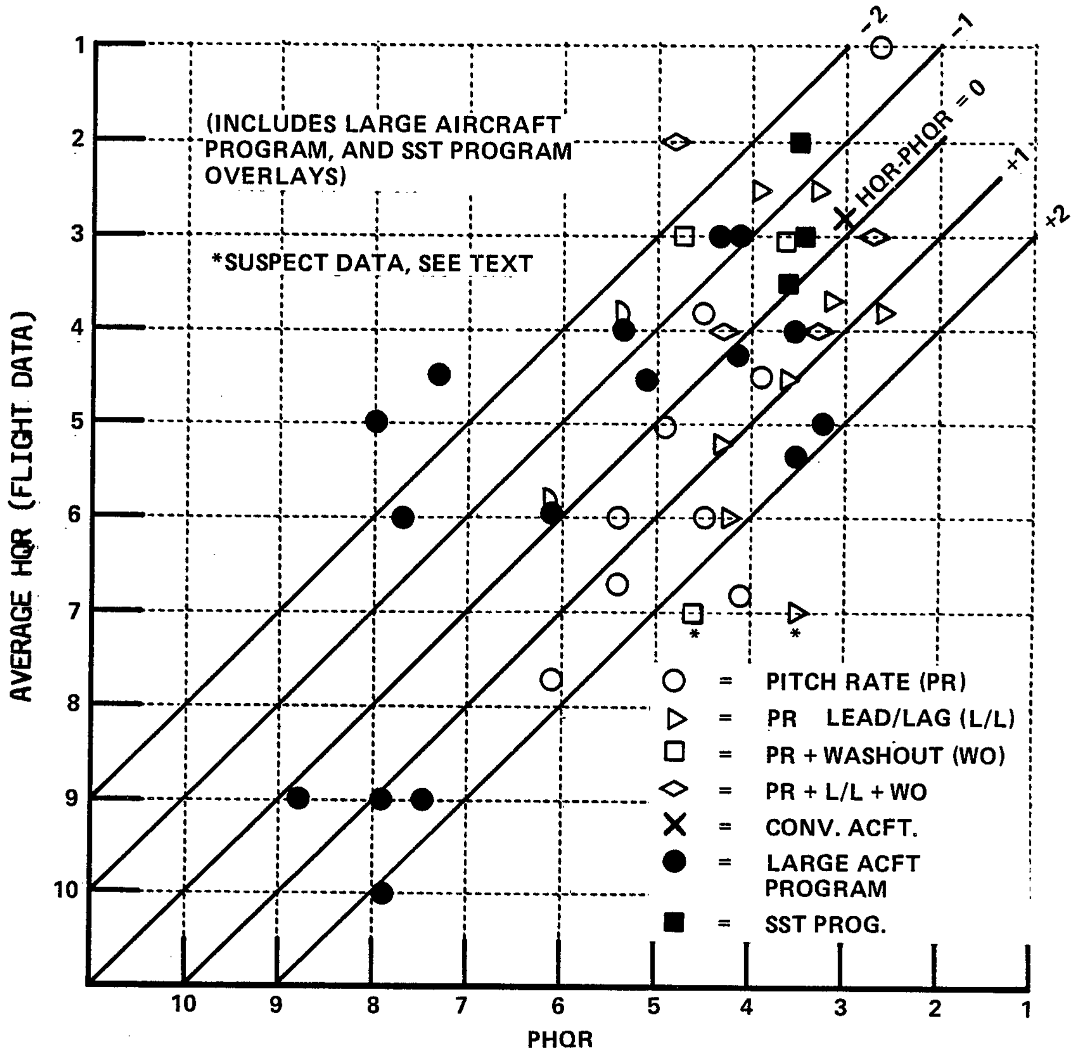
(Note that all pitch rate data points are shown, however, Configurations 4-7-7 and 8-2-5-1 were not used in the development of the criteria nor are they included in the numerical results).

4.2.3.11 Correlation of Time Domain Criteria With Other Classical Predictive Criteria

An attempt was made to compare time domain criteria and the classical frequency domain criteria used in the analysis for relative correlation with flight data.

Since some of the criteria predict flying qualities levels rather than HQR numbers, the time domain criteria and $\dot{h}$ bandwidth were converted to flying qualities levels by the following relationships:

Level 1	=	HQR 1 to 3
Level 1-2	=	HQR 3 to 4
Level 2	=	HQR 4 to 6
Level 2-3	=	HQR 6 to 7
Level 3	=	HQR 7 to 10



$$PHQR = 1.7\,\dot{\alpha}' - 1.44\,N'_{z_p} + 0.55\,T'_\alpha + 3.9$$

WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\ , \quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

$$T'_\alpha = |T_\alpha - 1| \left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05}\right]$$

$$(\text{for } T'_\alpha > 6\ ,\ \text{let } T'_\alpha = 6.0)$$

Figure 57 PREDICTED HQR (PHQR) VS. FLIGHT HQR (HQR) (FINAL APPROACH AND FLARED LANDING) PITCH RATE PROGRAM

Table 9
COMPARISON OF FLIGHT DATA
WITH VARIOUS PREDICTIVE CRITERIA
(Flying Qualities Levels)

CONFIG.	FLIGHT DATA HQR	FLIGHT DATA	BANDWIDTH CRITERIA (on θ)	EQUIV. SYSTEMS CRITERIA	NEAL-SMITH CRITERIA (on θ)	BANDWIDTH CRITERIA (on $\dot{h}$)	TIME DOMAIN CRITERIA
1-1-1	6.0	2-3	2(0)	2(0)	1(=)	3	2(0)
1-2-2	6.8	2-3	2(0)	2(0)	1(=)	-	2(0)
1-3-7	4.5	2	2(+)	2(+)	1(-)	1-2(0)	1-2
2-1-1	6.0	2	2(+)	2(+)	1-2(0)	3(-)	2(+)
2-2-2	3.8	1-2	2(0)	2(0)	1-2(+)	3(-)	2(0)
3-1-3	5.8	2	2(+)	2(+)	1(-)	3(-)	2-3(0)
3-2-4	3.8	1-2	2(0)	3(-)	1(-)	3(-)	2(0)
4-1-1	3.8	1-2	2(0)	2(0)	-	1(0)	1(0)
4-2-2	2.5	1	2(-)	2(-)	1(+)	1(+)	1-2(0)
4-3-7	7.0	3	2(-)	2(-)	1(=)	1-2(-)	1-2(-)
4-3-7-1	4.0	2	2(+)	2(+)	1(+)	1(0)	1-2(0)
5-1-1	4.5	2	2(+)	2(+)	2(+)	1-2(0)	1-2(0)
5-2-2	2.5	1	2(-)	2(-)	1(+)	1-2(0)	1-2(0)
6-1-1	5.0	2	2(+)	2-3	1(-)	3(-)	2(+)
6-1-1-1	3.0	1	2(-)	2(-)	1(+)	2-3(=)	1-2(0)
6-2-1	3.7	1-2	2(0)	2(0)	-	1(0)	1-2(+)
6-2-1-1	3.0	1	2(-)	1-2	-	1(+)	1(+)
7-1-4	2.8	1	2(-)	2(-)	1(+)	1(+)	1(+)
8-1-5	5.2	2	2(+)	2(+)	1-2(0)	2(+)	2(+)
8-1-5-1	2.0	1	2(-)	2(-)	2-3(=)	1-2(0)	2(-)
8-2-5	7.7	3	2(-)	2(-)	2(-)	3(+)	2-3(0)
8-2-5-1	7.0	3	2(-)	2(-)	1(=)	-	2(-)
8-3-5	6.7	3	3(+)	3(+)	2(-)	3(+)	3(0)
8-3-5-1	3.0	1	3(=)	3(=)	2(-)	3(=)	2(-)
8-4-6	1.0	1	2(-)	2(-)	1-2(0)	1(+)	1(+)
8-5-5	6.0	2	3(-)	2-3	2(+)	2(+)	2(+)
8-5-5-1	4.0	2	3(-)	2(0)	2-3(-)	1-3(+)	2(+)
			No./%				
No Grade			0/0	0/0	3/11%	2/7%	0/0
Error = 2 Levels (=)			1/4%	1/4%	4/17%	2/8%	0/0
Error = 1 Level (-)			13/48%	11/41%	8/33%	6/24%	4/15%
Error < 1 Level (0)			6/22%	9/33%	5/19%	8/32%	14/52%
Error = 0 Level (+)			7/26%	6/22%	7/29%	9/36%	9/33%
Total < 1 Level Error			48%	55%	48%	68%	85%

HQR 1.0 - 3.0 = Level I
HQR 3.0 - 4.0 = Level 1-2
HQR 4.0 - 6.0 = Level 2
HQR 6.0 - 7.0 = Level 2-3
HQR 7.0 - 10.0 = Level 3

This "level data" was then compared with bandwidth criteria (on θ), equivalent systems criteria, and Neal-Smith criteria (on θ) in Table 9 of Appendix K. The results are completely tabulated in Table 9, however, a summary of the results are:

Criteria	Configurations predicted to within less than one flying qualities level of flight data:
Bandwidth (on θ)	48%
Equivalent Systems	55%
Neal-Smith (on θ)	48%
Bandwidth (on $\dot{h}$)	68%
Time Domain	85%

4.2.3.12 Time Delay Parameters

There was not sufficient time delay change in the pitch rate data base to develop a time delay parameter. Consequently, the time domain criteria presented is only applicable to maximum time delay (effective plus transport) of 170 ms from stick force to aircraft motion (pitch rate). The development of a time delay parameter appears quite feasible but requires a larger flight data base generated in a controlled experiment.

4.3 DISCUSSION OF RESULTS AND ANALYSIS

The purpose of this experiment was to examine the cause of poor pilot ratings of pitch rate command flight control systems in the flared landing task and to determine if pitch rate overshoot was a significant factor. The results of the investigation yielded many more answers than expected thus the subsequent conclusions extend beyond the original scope of the experiment.

It appears that several design approaches will provide flight control systems that demonstrate Level 1 flying qualities in the flared landing task. The experiment illustrated a number of reasonable methods that will be discussed in the following paragraphs. All of the approaches must first take into account how the pilot executes a flared landing and what cues he requires

in order to execute the landing with predictability and precision. This experiment also provided more insight into pilot requirements in the task and comments will also be offered in this regard.

4.3.1 Pilot Requirements in the Flared Landing Task

The flared landing task requires the pilot to very accurately control flight path, or more specifically altitude rate ($\dot{h}$) in the final few feet prior to touchdown. This is particularly true for small airplanes (i.e., low eye height) where depth perception is very good and consequently the pilot can stay tightly in the loop in the final landing phase. In larger aircraft i.e., high eye height, 30 ft or greater, the technique is more towards "open loop" type landing where an acceptable rate of descent is selected subsequent to pre-flare and the pilot normally does not tightly enter the loop close to the ground (i.e., he "hangs on" until touchdown). The eye height in the experiment was approximately 12 feet which is representative of fighter size aircraft.

The $\dot{h}$ loop is slow even for normally attainable short period frequencies and the pilot requires feedback cues other than $\dot{h}$ in order to achieve consistently good results. In a normal aircraft (those with conventional short period and phugoid) an excellent cue is stick force because stick force controls angle of attack and rate of change of flight path. This results in an increasing average pull force during the flare as the speed bleeds off and the angle of attack must be increased. In many cases this cue alone was sufficient for Level 1 performance and pilot ratings.

An additional cue is cockpit vertical acceleration (N_{z_p}) that is provided by pilot location relative to the center of rotation. If the pilot is located in front of the rotation center this cue is supportive in that it provides an indication of control direction and magnitude. If the pilot is located behind the center of rotation i.e., shuttle orbiter, this is a negative cue and with the lack of proper stick force cues can be quite detrimental. If the N_{z_p} cue is in the proper direction and large enough, Level 1 performance might be achieved even in the absence of stick force cues.

4.3.2 Design Methods to Achieve Proper (Monotonic) Stick Force Cues in the Landing Flare

1. Feed back angle of attack and pitch rate to obtain conventional short period and phugoid root locations, that meet MIL 8785 Level 1 requirements.

2. If angle of attack feedback is not feasible and integral- proportional pitch rate feedback is the best feasible approach:

   a. Position the pseudo short period roots to meet MIL 8785 Level 1 requirements.

   b. Apply a lead/lag pre-filter in the command path to cancel the λ_2' root and thus restore the $1/\tau_{\theta_2}$ zero, and to cancel the control system zero.

   c. And/or apply a washout pre-filter in the command path to assure monotonic stick forces.

The washout pre-filter should be implemented only during the landing flare. Washout implementation in the approach would require a turn compensation similar to that used in the experiment or some other method to provide normal control. In addition, some method of removing the washout in event of go-around should be considered.

4.3.3 Design Methods to Achieve Pilot Station Acceleration Cues in the Landing Flare

1. Location of the pilot relative to the center of rotation is the primary factor in N_{z_p} levels and this is a function of aircraft configuration. Aircraft configuration is a result of many other compromises and it is doubtful that flying qualities in the landing flare would dictate the final configuration.

2. The lead/lag filter of the previous paragraph will improve N_Z cues unless the pilot is located quite close to the center of rotation.

3. Active direct lift controls can control pilot station accelerations to an extent.

Section 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

1. Current integral-proportional pitch rate command flight control systems can provide excellent attitude control i.e., pitch pointing. However, although good attitude control is a prerequisite for the flared landing task it is not sufficient to provide Level 1 performance.

2. The pilot requires "surrogate" feedback cues to precisely control flight path in the landing flare. For conventional short period and phugoid dynamics he can use the following cues:

   - Initial acceleration at the pilot station.
   - Stick deflection and stick force are related to angle of attack and flight path.
   - Initial attitude response during short period transient reflects commanded angle of attack.
   - Longer term pitch rate and attitude indicates flight path rate and flight path angle.

   In the case of rate command attitude hold systems, the stick commands pitch rate and the control sytem holds pitch attitude when the stick command is zero. Stick deflection and pitch rate are nearly proportional but neither give very useful cues as to what angle of attack and flight path are doing. This is because the control system causes two of the dynamic modes to be decoupled from the pitch rate and attitude responses but not from the angle of attack or flight path responses. The augmented roots near $1/\tau_{\theta_1}$ and $1/\tau_{\theta_2}$ are cancelled in the pitch attitude transfer function but not in alpha or gamma. These dynamic modes are excited by pilot control actions and cause continuous variation of angle of attack, flight path and speed but not pitch attitude. Thus two primary cues normally used by

the pilot (i.e., stick feel and pitch attitude) as "surrogates" for controlling flight path are reduced in value for this purpose because the control system decouples the pitch attitude from the dynamic responses of angle of attack, flight path angle and airspeed.

3. The most direct way to provide these cues and consequent Level 1 landing performance is to utilize angle of attack and pitch rate feedback to achieve "conventional" short period and phugoid characteristics.

4. Integral-proportional pitch rate flight control systems can be improved to Level 1 flared landing performance by the use of lead/lag and washout pre-filters in the command path. The lead/lag filter provides required initial response characteristics which include improved angle of attack response. This provides better flight path control and improved acceleration cues to the pilot. The washout filter changes the response to stick commands from q, $\dot{\alpha}$ and $\dot{\gamma}$ to θ, α and γ at low frequencies. This permits the pilot to use continuous proportional control instead of mandulated pulse control and restores control feel during maneuvers.

5. Strong pilot station vertical acceleration cues (pilot in front of center of rotation) can provide Level 1 flared landing performance even in the absence of monotonic stick forces.

6. Lift curve slope effects i.e., $1/\tau_{\theta_2}$ do not appear to be a strong factor in achieving Level 1 flared landing performance. Level 1 performance can be achieved at $1/\tau_{\theta_2}$ values as low as 0.38. This experiment provided insufficient data to draw conclusions of $1/\tau_{\theta_2}$ values below 0.38 and greater than 0.72.

7. The relative location of pseudo short period roots of pitch rate flight control systems within MIL 8785 Level 1 boundaries for landing do not appear to be a factor in achieving Level 1 performance, however, the angle of attack short period frequency T_{α} can be a strong factor in the absence of stick force and acceleration cues (pitch rate command attitude hold systems cause an augmented root to be located near $1/\tau_{\theta_2}$, this makes the angle of attack response Third order and the bandwidth of control over the lift force is reduced).

8. Classical predictive criteria i.e., bandwidth criteria, equivalent systems criteria, Neal-Smith criteria, etc., when based on pitch attitude do not provide adequate flying qualities predictions for the flared landing task.

9. A closed-loop bandwidth criteria, when applied to altitude-rate ($\dot{h}$) significantly improves predictive capability but does not appear to pick up the effect of washout pre-filters. This criteria shows promise and further development of it is warranted.

10. Angle of attack and pilot station acceleration time histories provided strong correlation with flight data.

11. A time domain predictive criteria developed from the experiment and utilizing measurements from angle of attack and pilot station acceleration time histories to a step input was the most accurate criteria used in the data analysis. This criteria appears to apply as well to data from previous experiments. Maturity of this criteria requires a larger data base.

5.2 RECOMMENDATIONS

5.2.1 Washout Filter

The effects of the washout pre-filter have not been thoroughly explored. A flight program should be conducted to investigate the optimization of washout filter frequency and methods of implementing the pre-filter at appropriate points in the final approach.

5.2.2 Non-Flared Landings

The short comings of pitch rate command flight control systems in the flared landing task are well documented. It is quite possible that lack of monotonic stick forces may not be as detrimental in a non-flared landing. A flight program should be conducted using mirror type approaches to explore this application of pitch rate command systems.

5.2.3 Time Domain Criteria Refinement

The time domain criteria developed during the analysis of the experiment shows promise as a simple and direct method of predicting flying qualities for many different types of flight control systems. Refinement of this criteria is required in the areas of effects of alpha (α) short period frequency, and time delay.

A three phased approach to this refinement is recommended:

Phase I — Conduct a data search of previous flight programs to extend the data base of this experiment and to identify areas where further data is required.

Phase II — Conduct a controlled flight experiment to extend the data base of Phase I and to specifically provide adequate time delay and short period frequency coverage.

Phase III — Using the data of Phase I and II perform a thorough analysis with a goal of refining the time domain criteria.

5.2.4 Altitude Rate Bandwidth Criteria

The application of altitude rate bandwidth analysis also shows promise as a more accurate predictor of flying qualities in the landing task. This approach should be included and refined in the Phase III effort recommended above.

5.2.5 Alpha Limiter Application

An alpha limiter was incorporated into the flight control design of this experiment but was not tested due to flight time restraints. Proper implementation of an alpha limiter could tend to produce monotonic stick forces in the landing flare similar to the effects of the washout pre-filter. Effects of the alpha limiter should be included in the flight investigation recommended in 5.2.1.

Section 6

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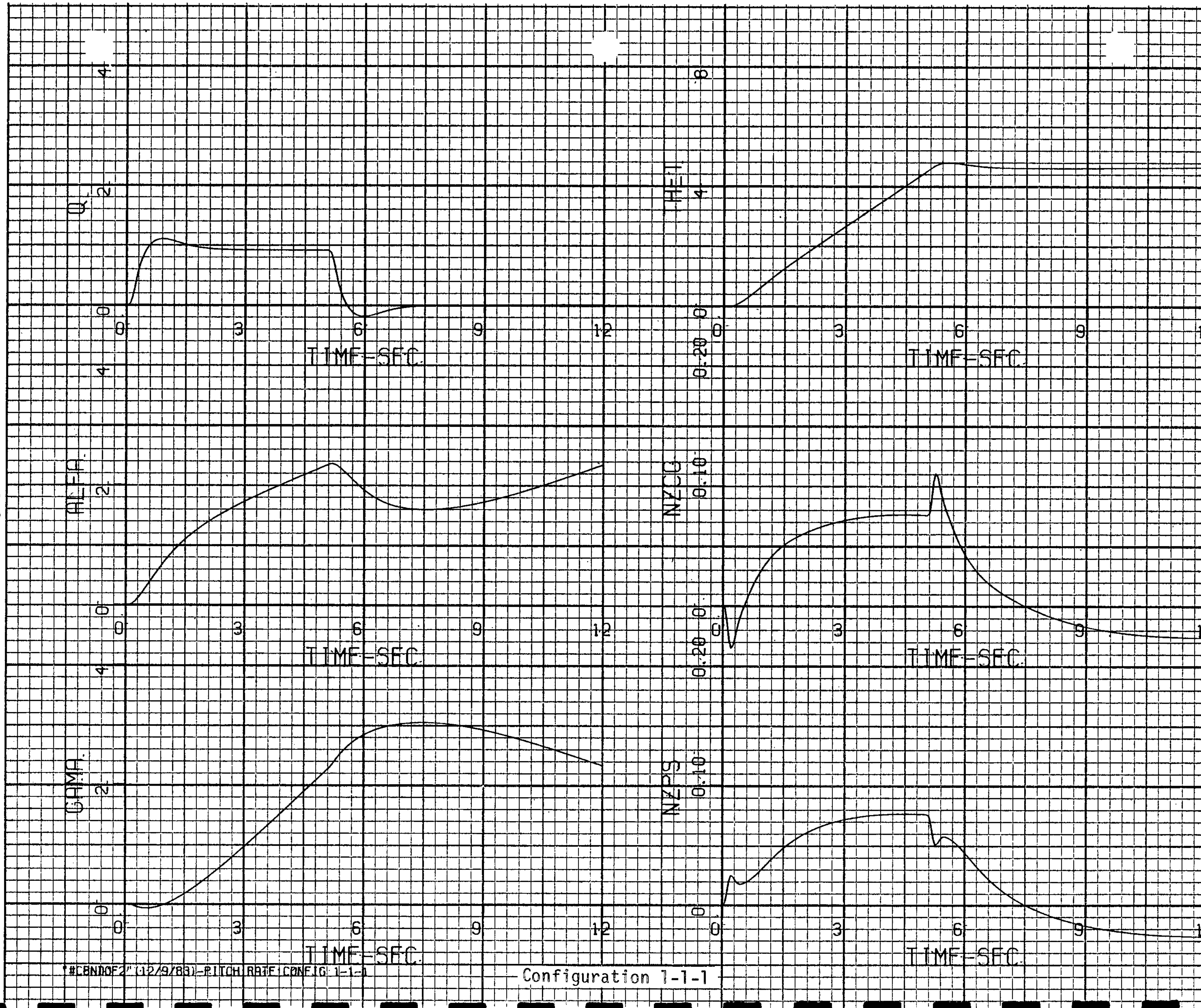
APPENDIX A

COMPUTER TIME HISTORIES
(5 sec Step In, Step Out)



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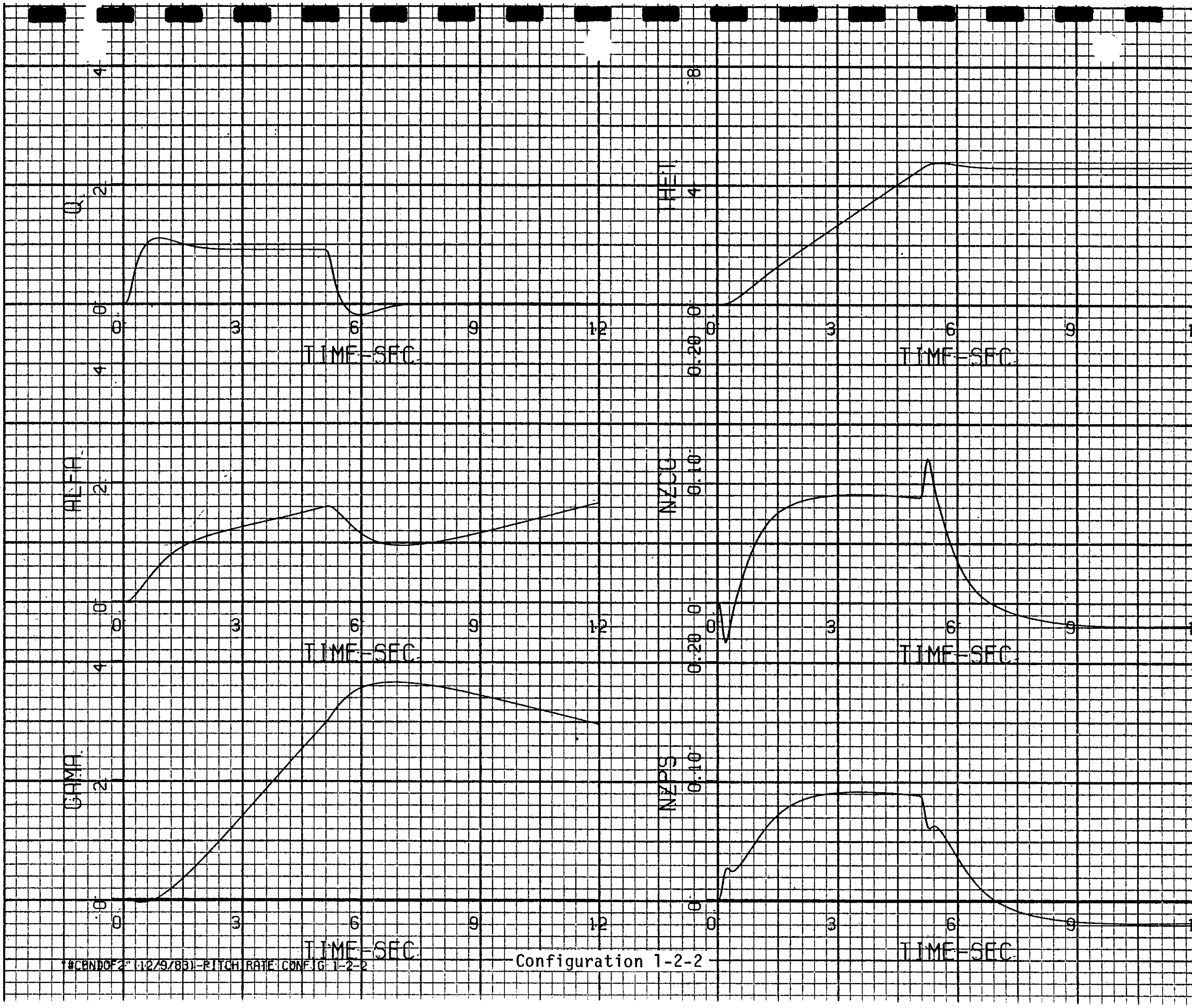

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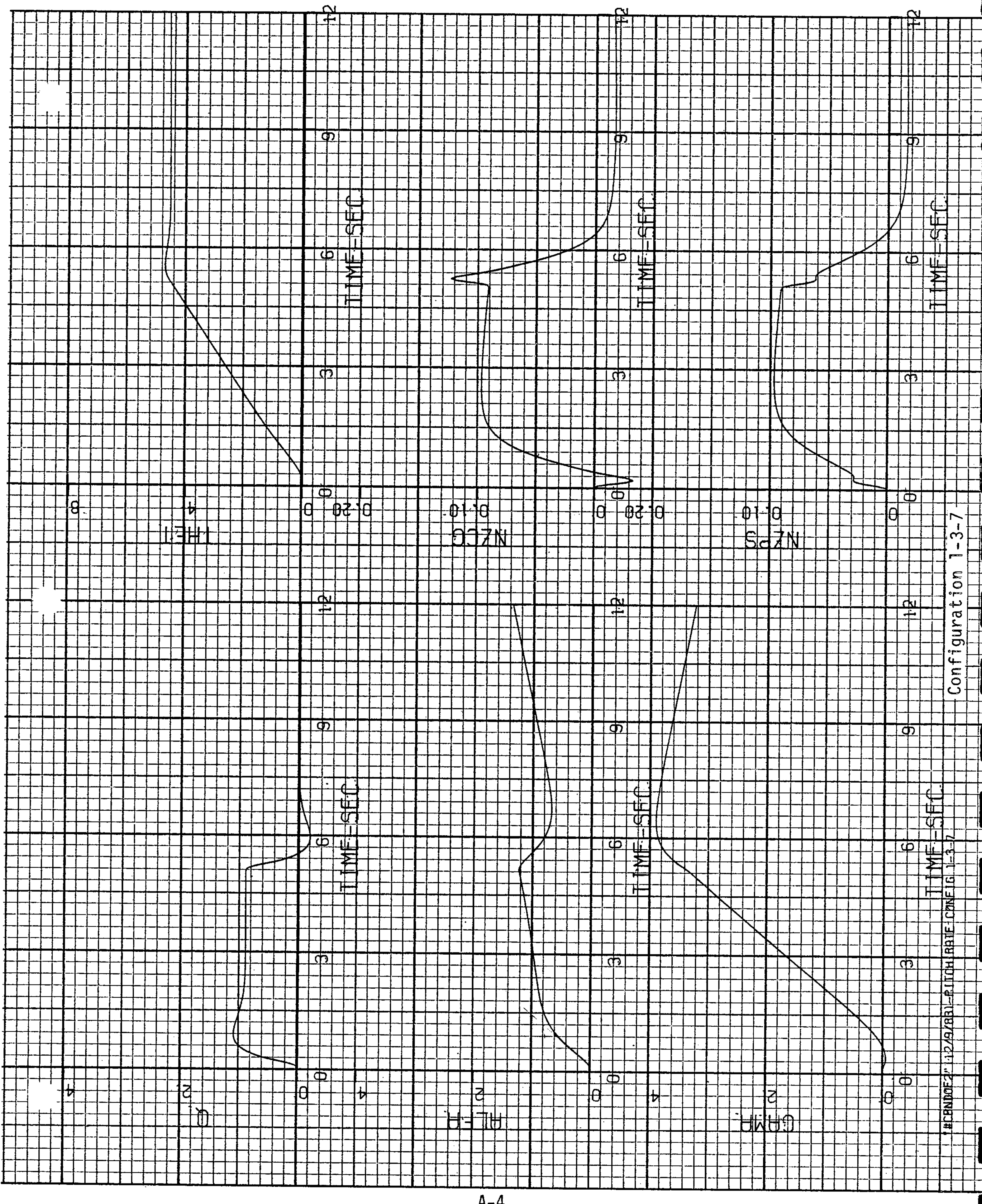

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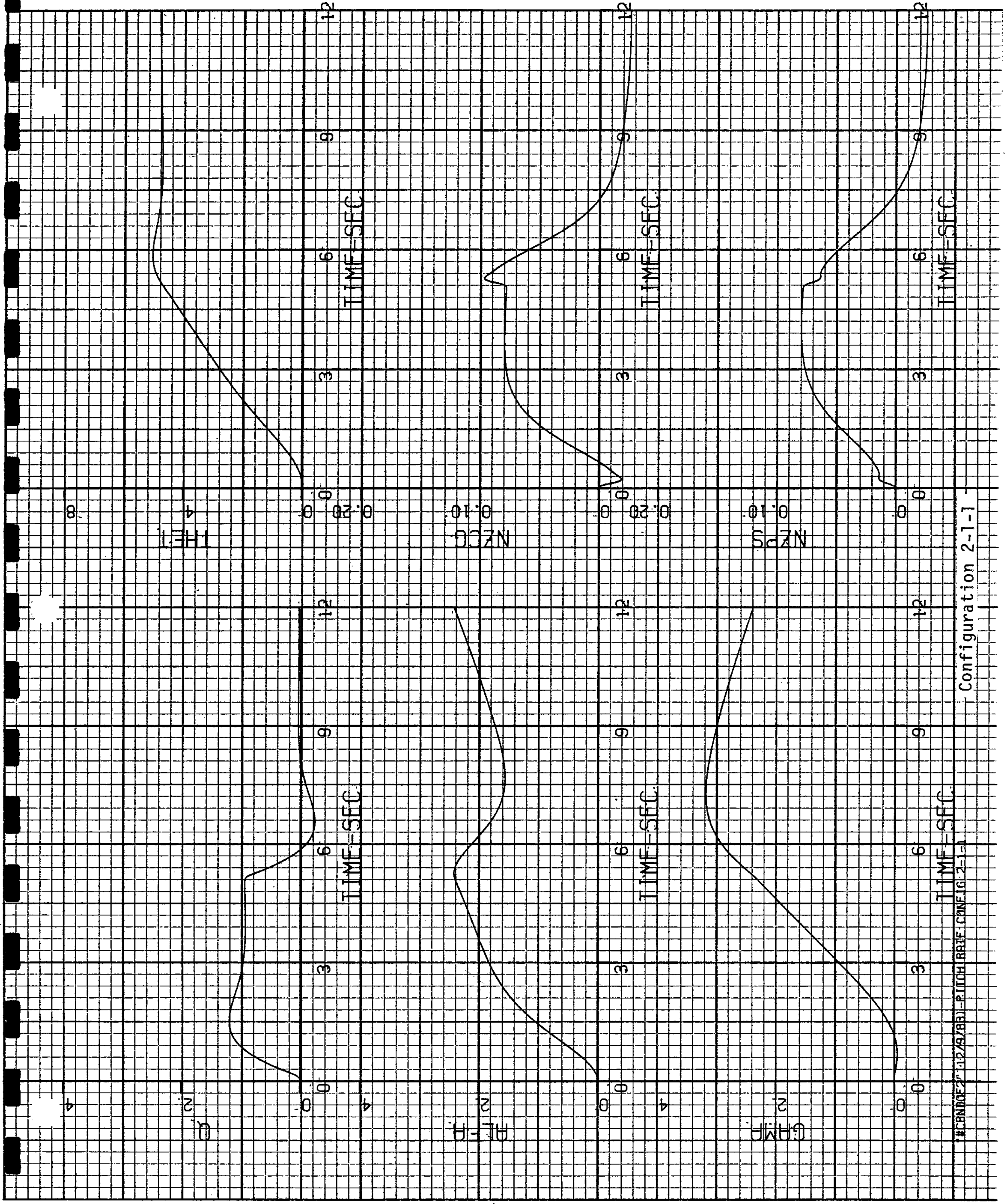

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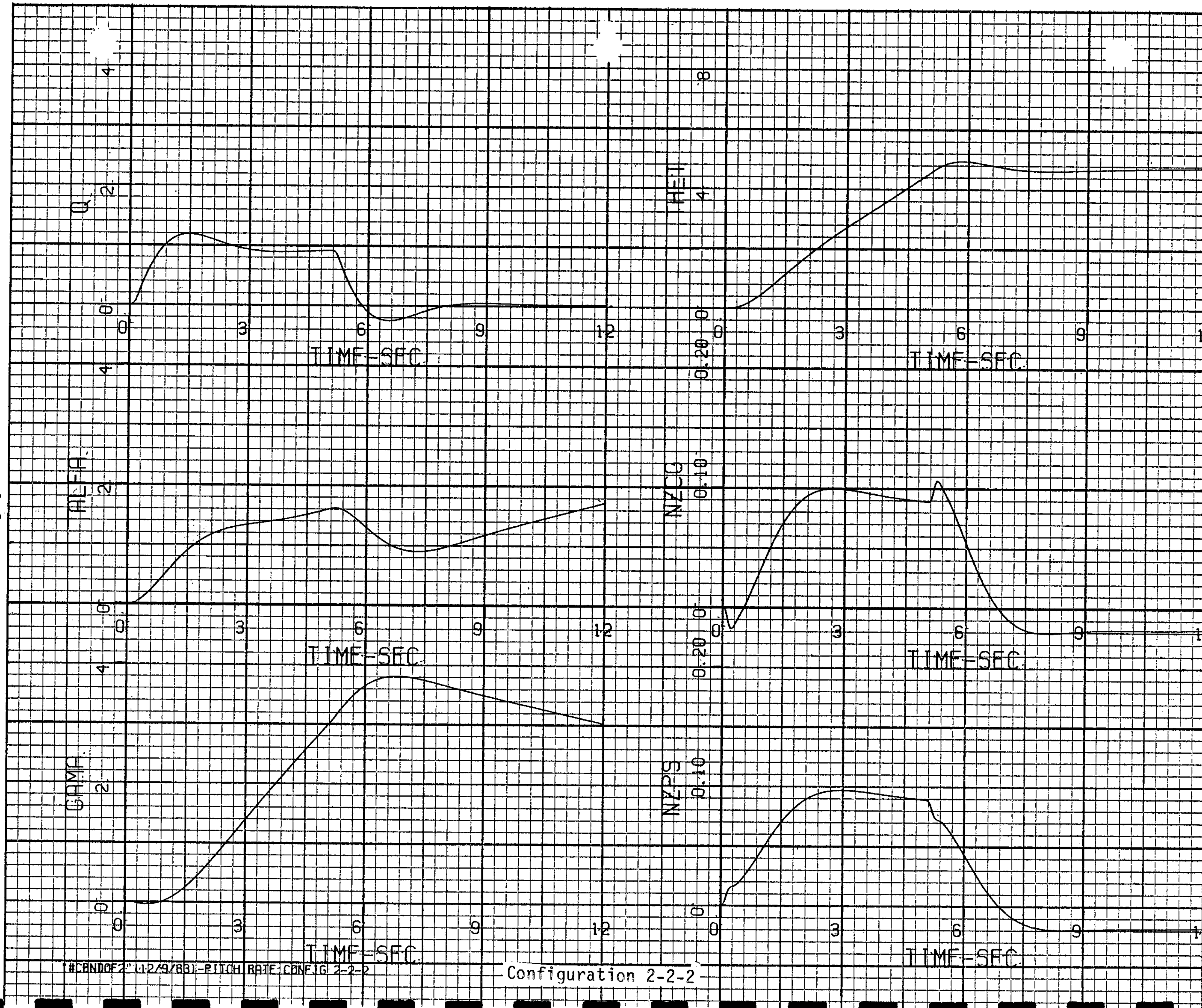

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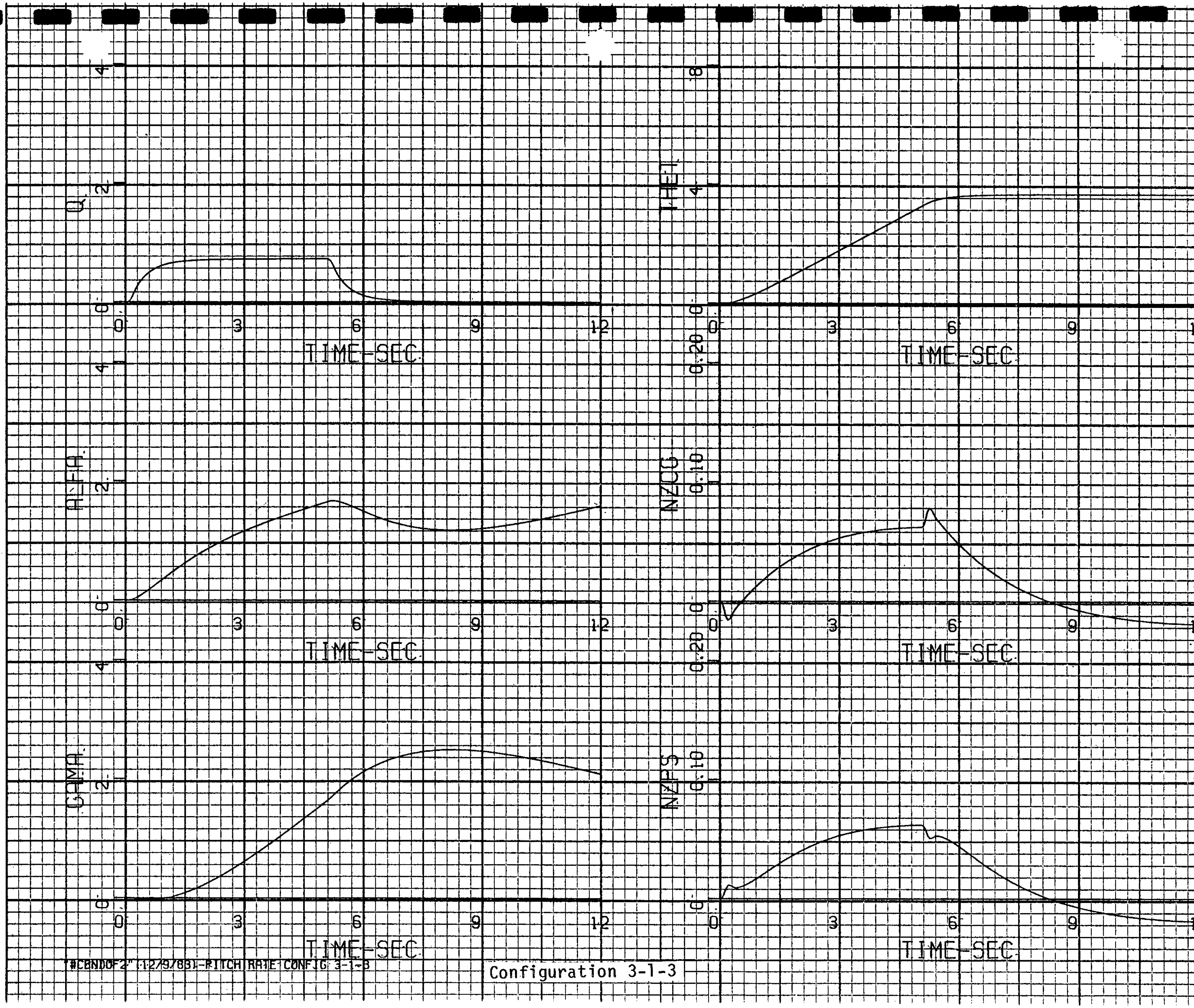

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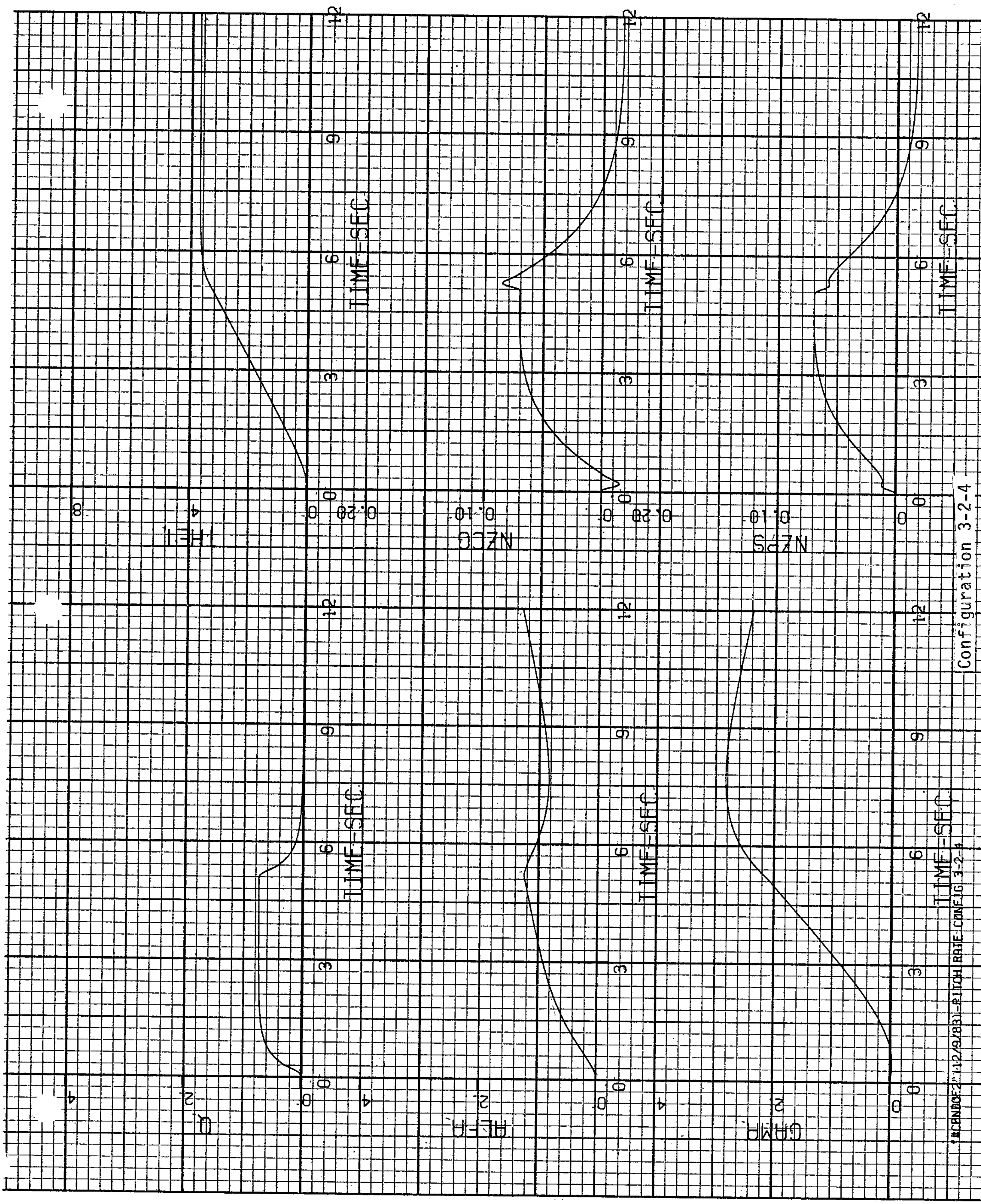
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NZCG
NZPS
Q
ALFA
GAMA
TIME-SEC
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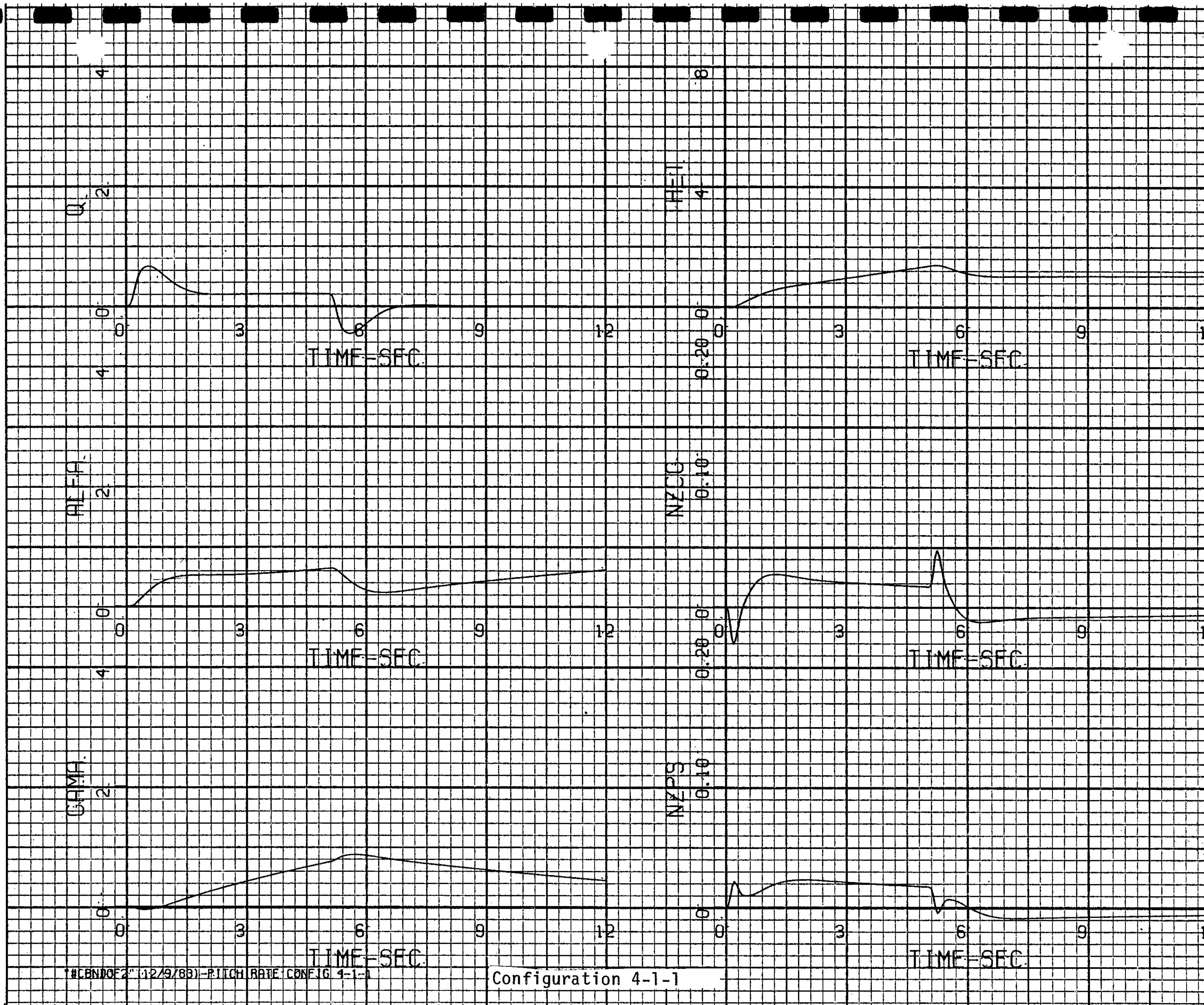
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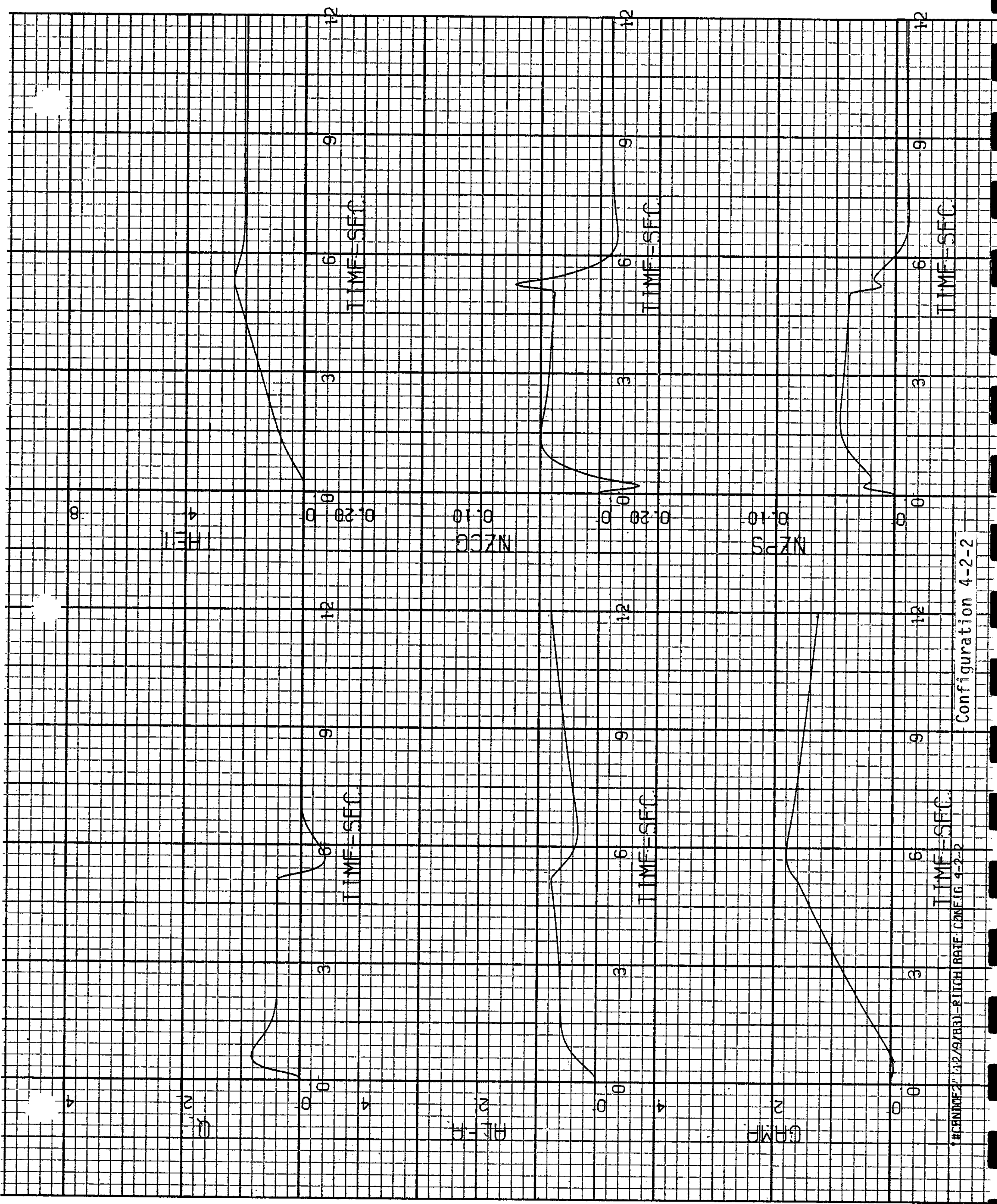
Configuration 4-1-1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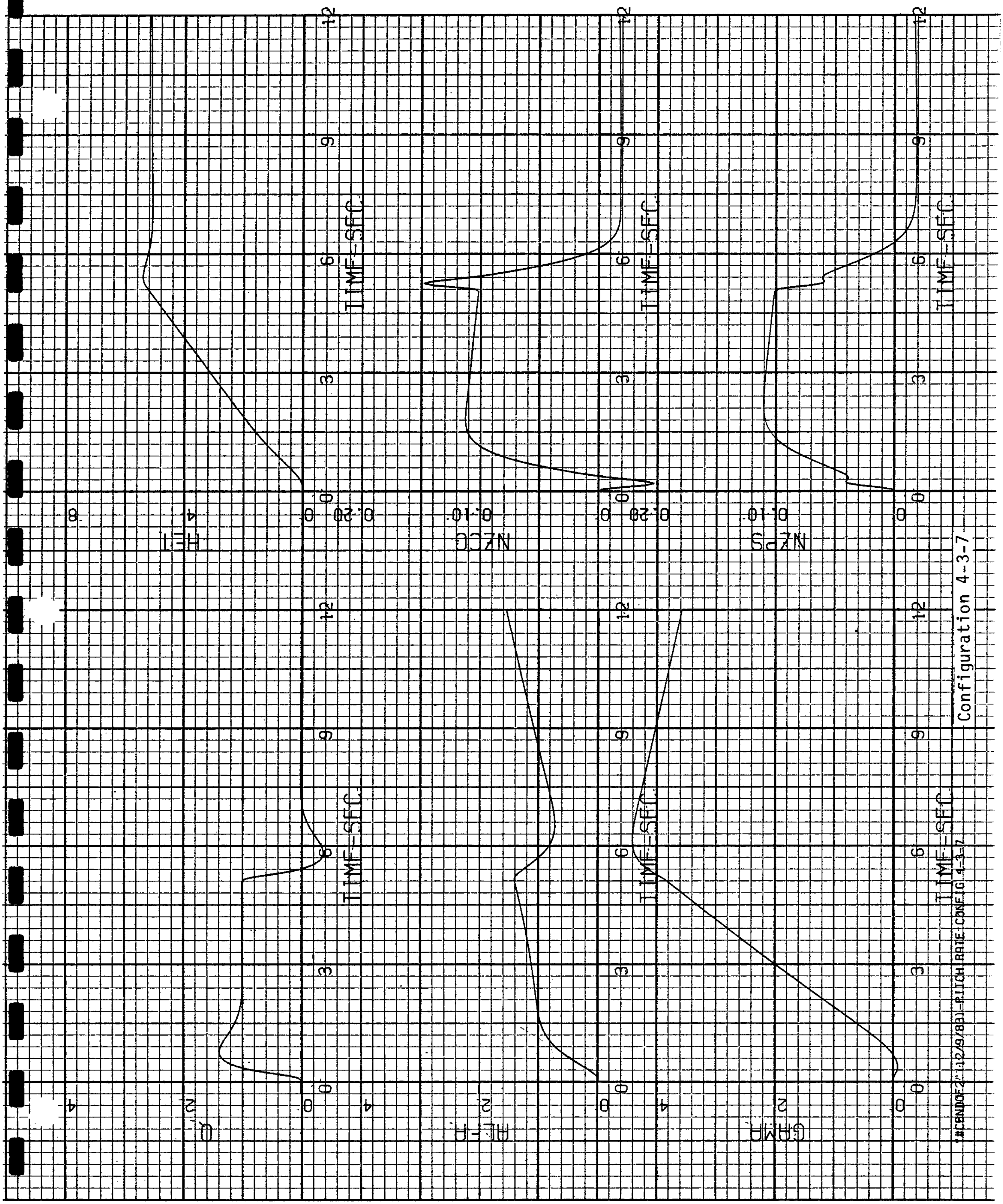

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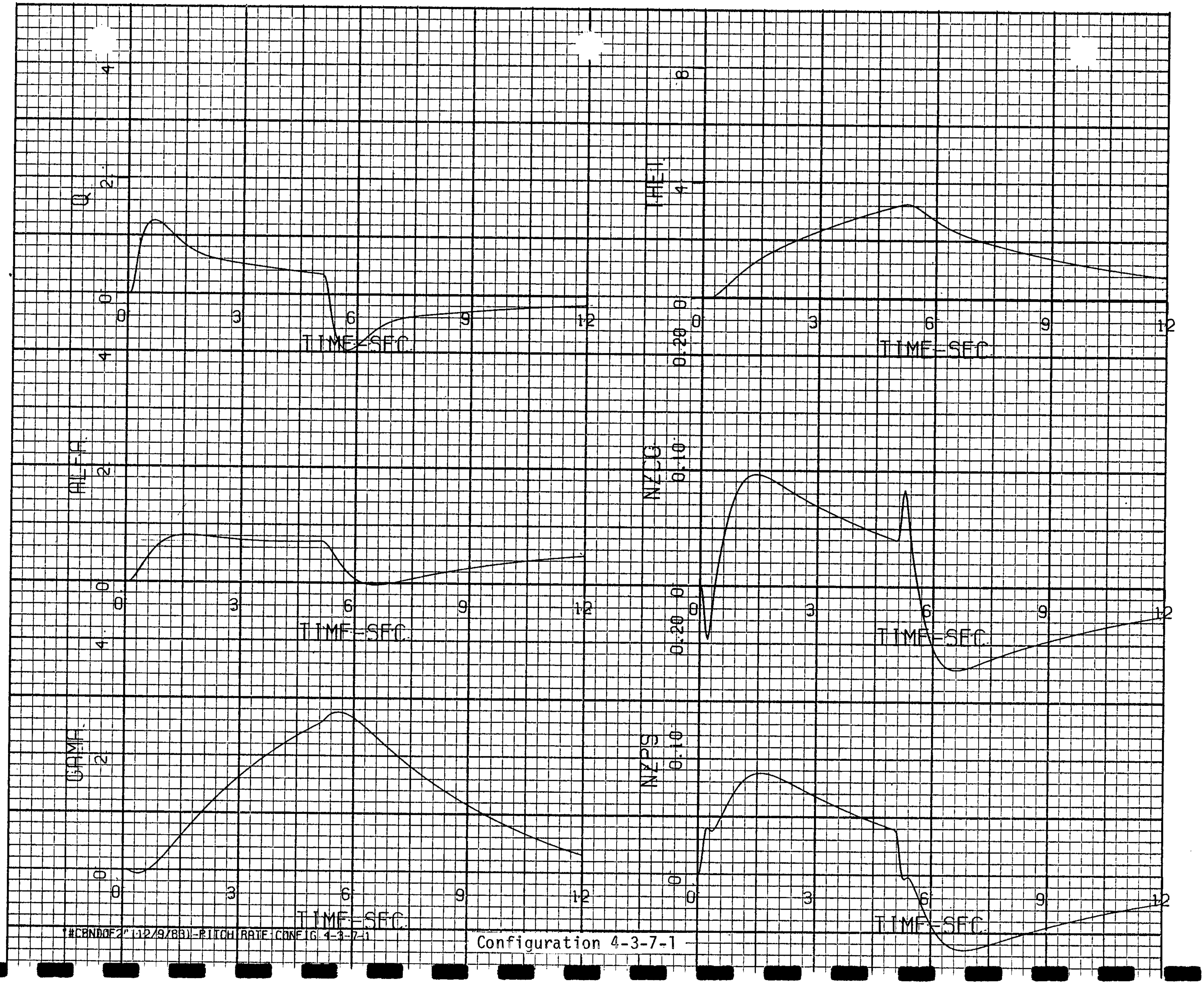

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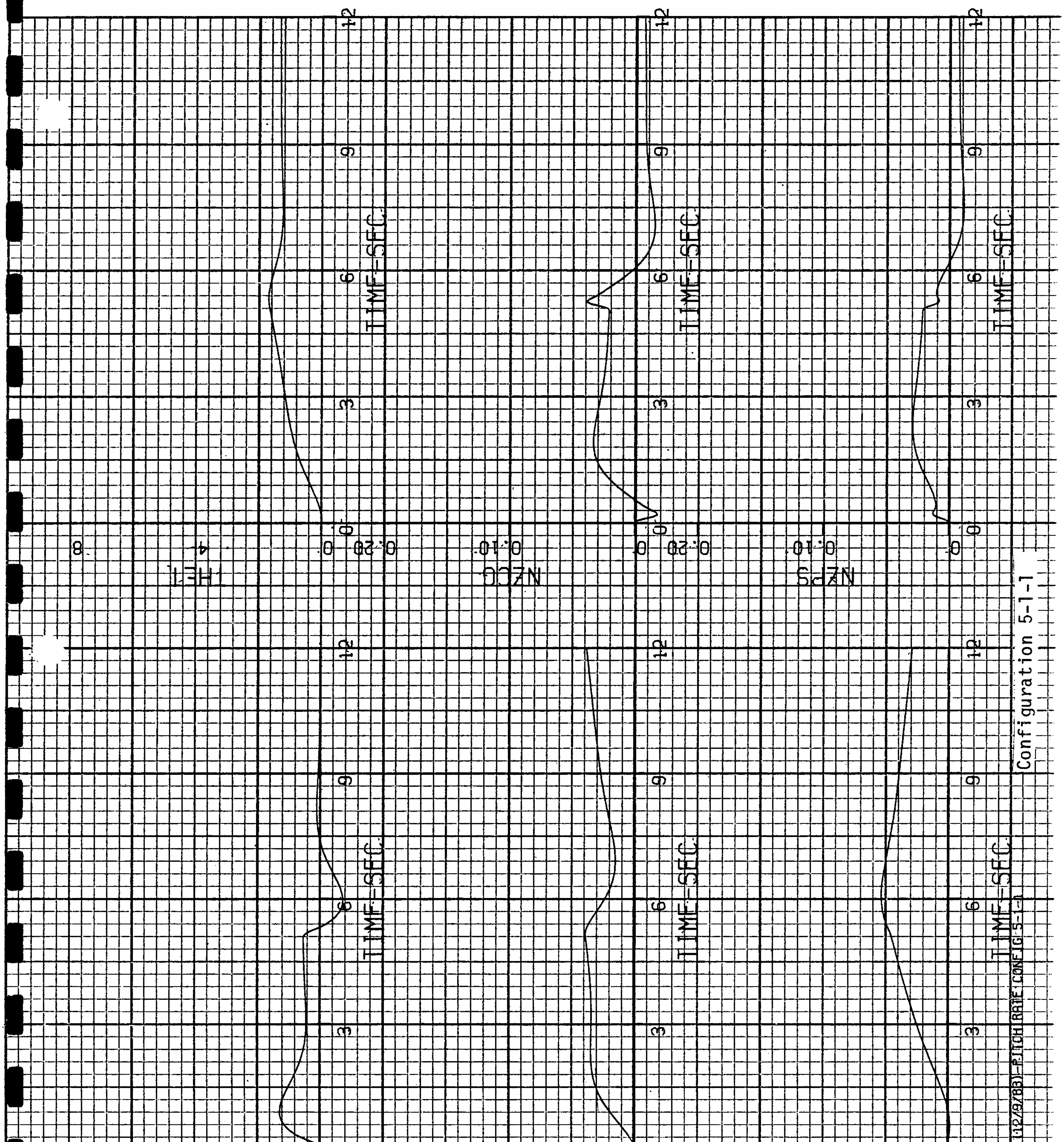

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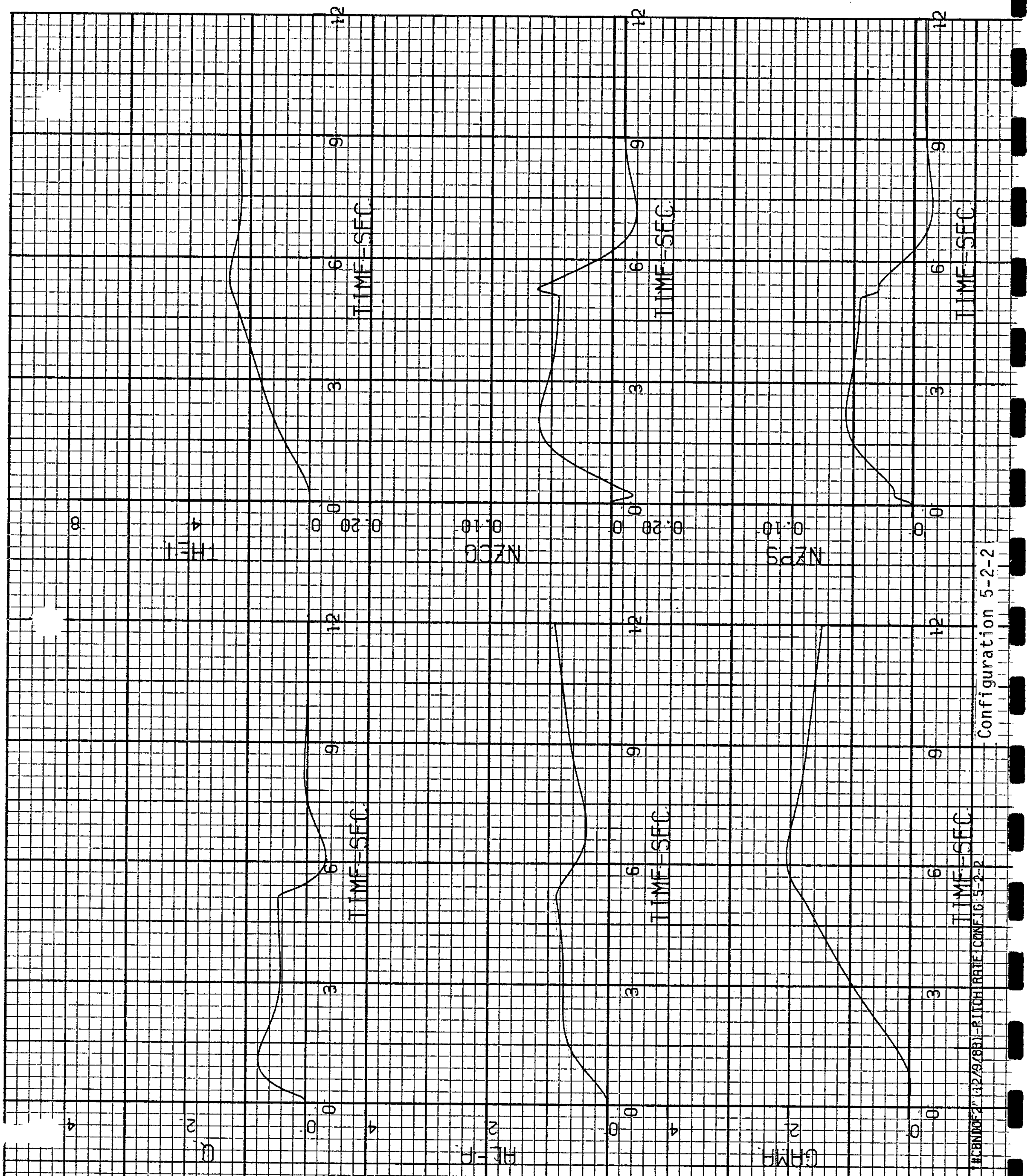
TIME-SEC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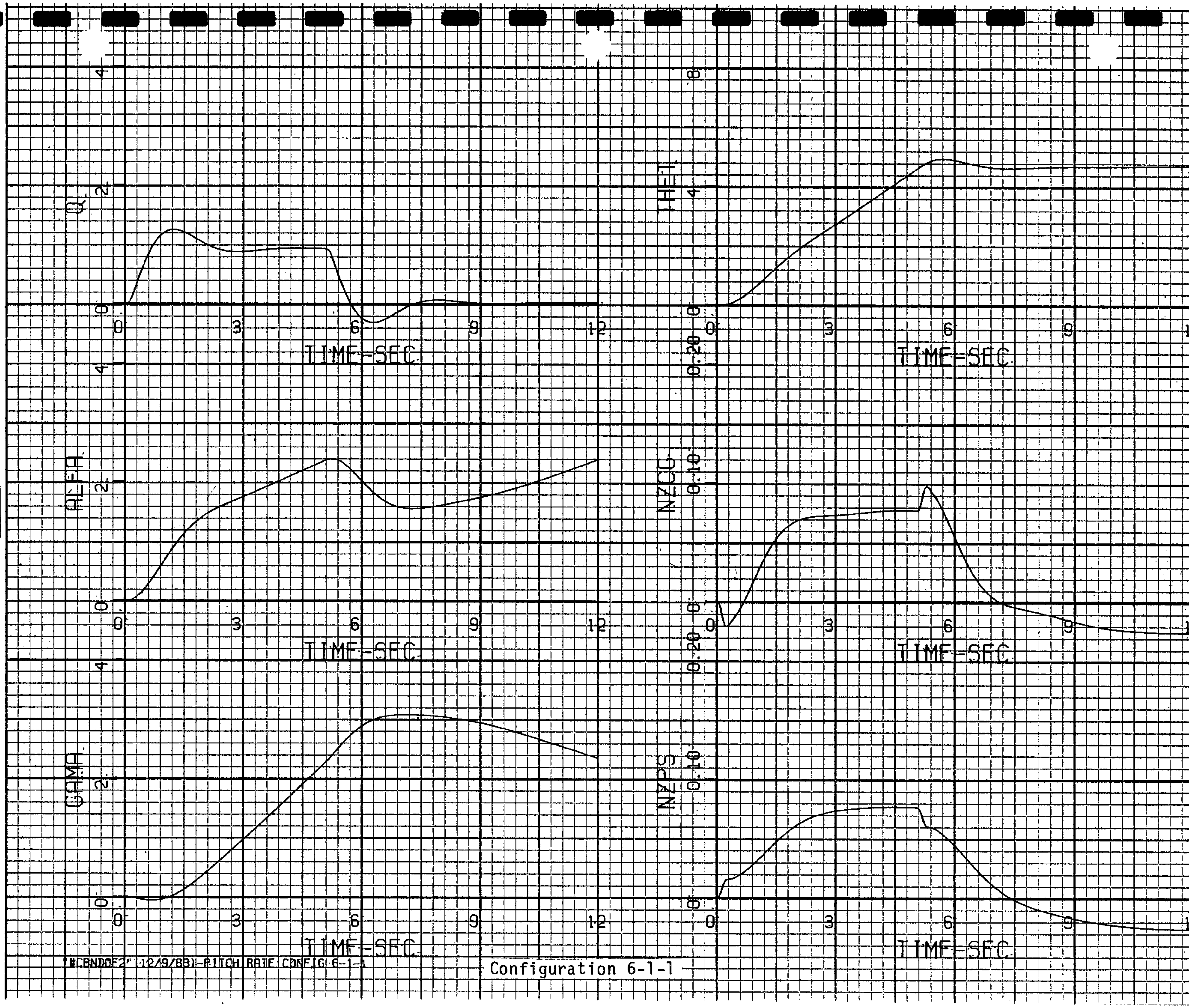
GAMA



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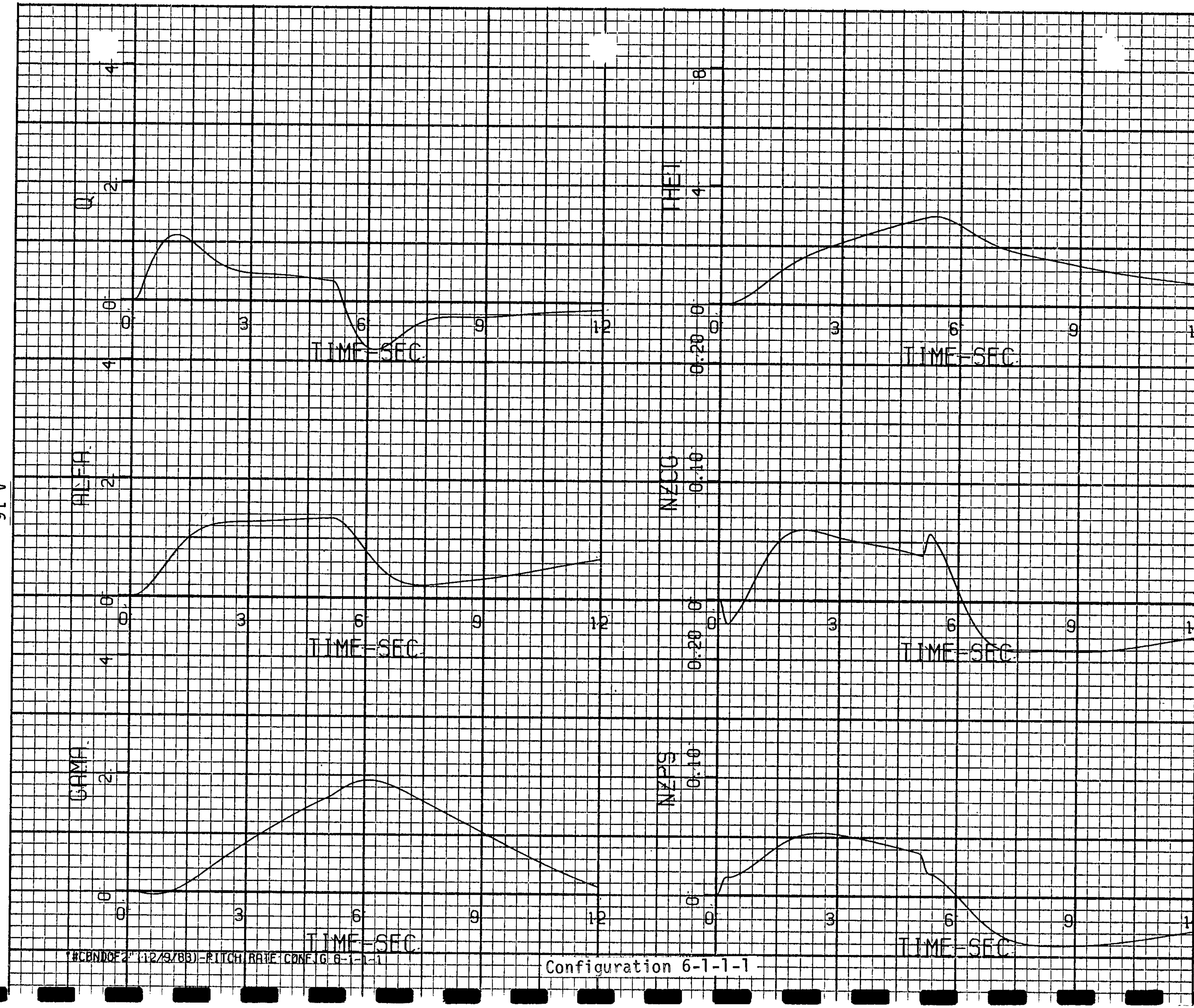

Configuration 6-1-1-1

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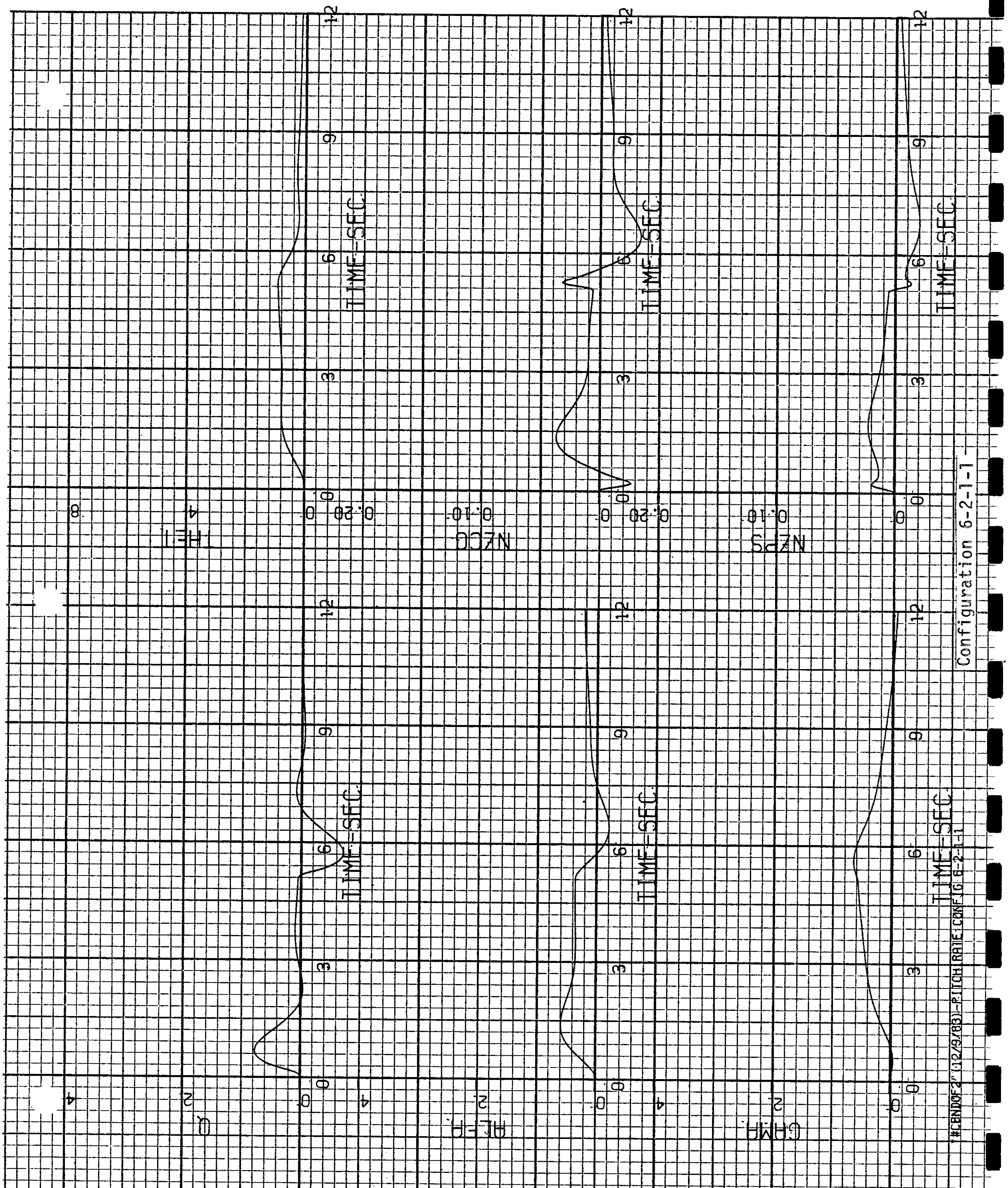
Configuration 6-2-1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Q
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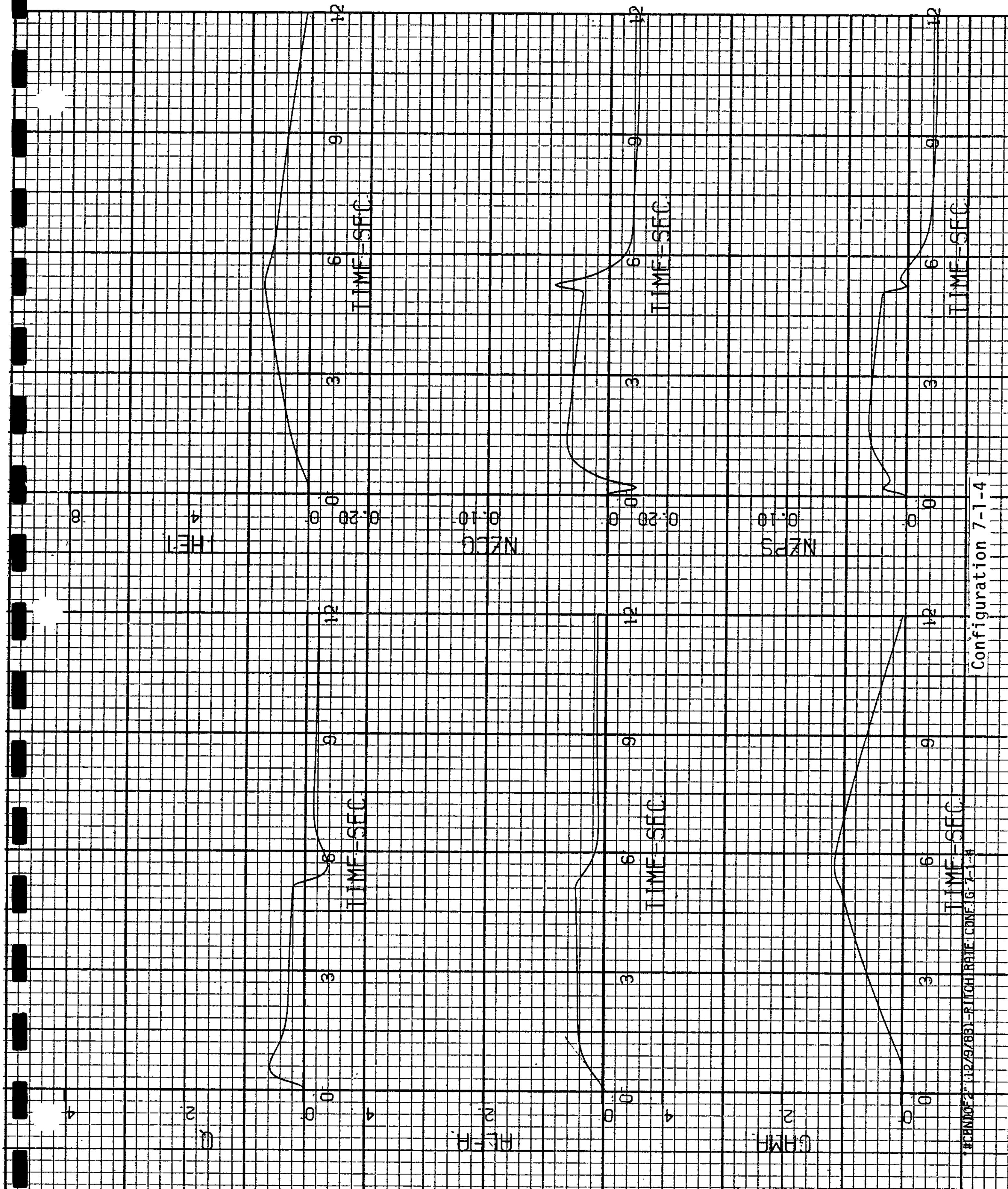
TIME-SEC



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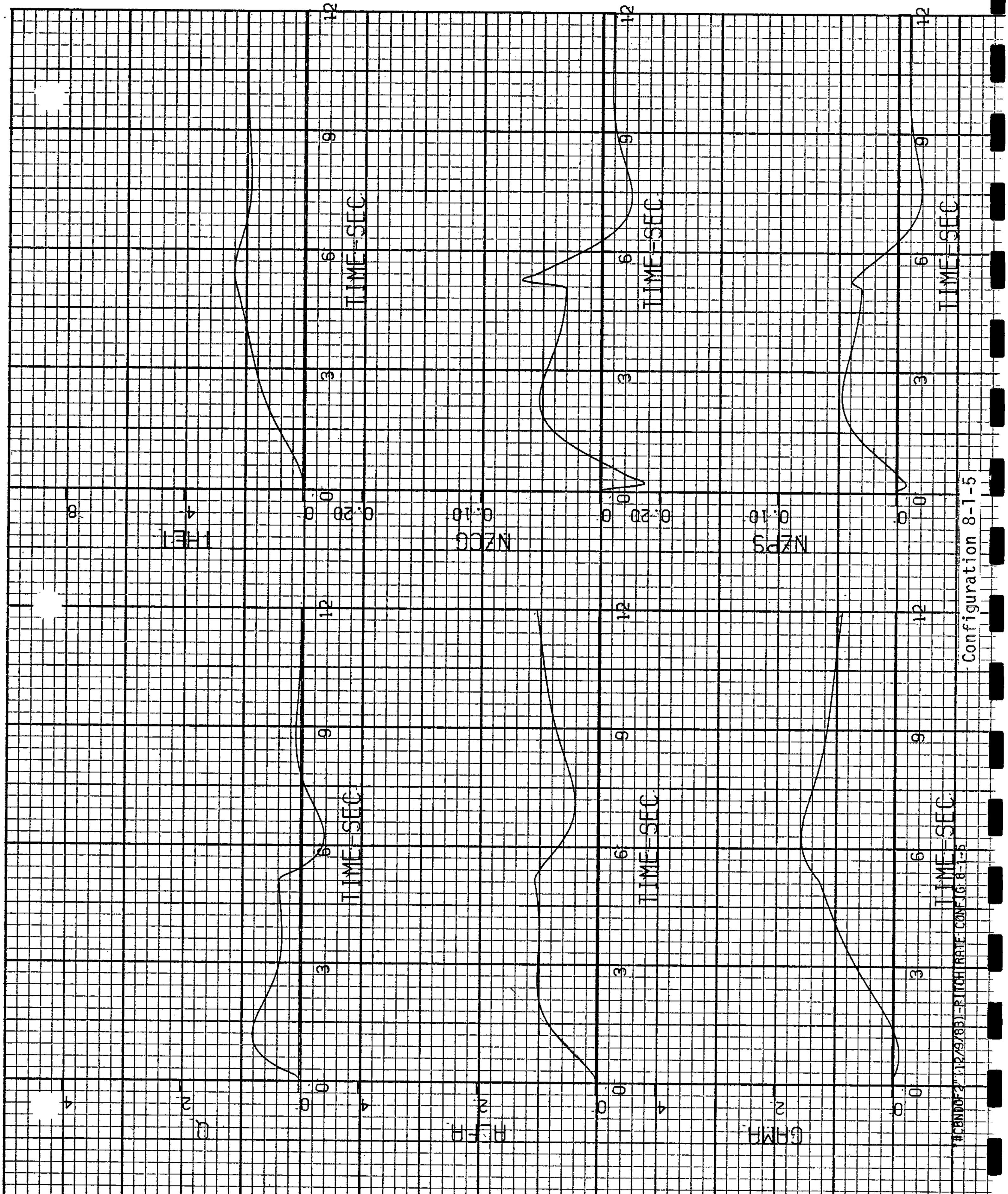
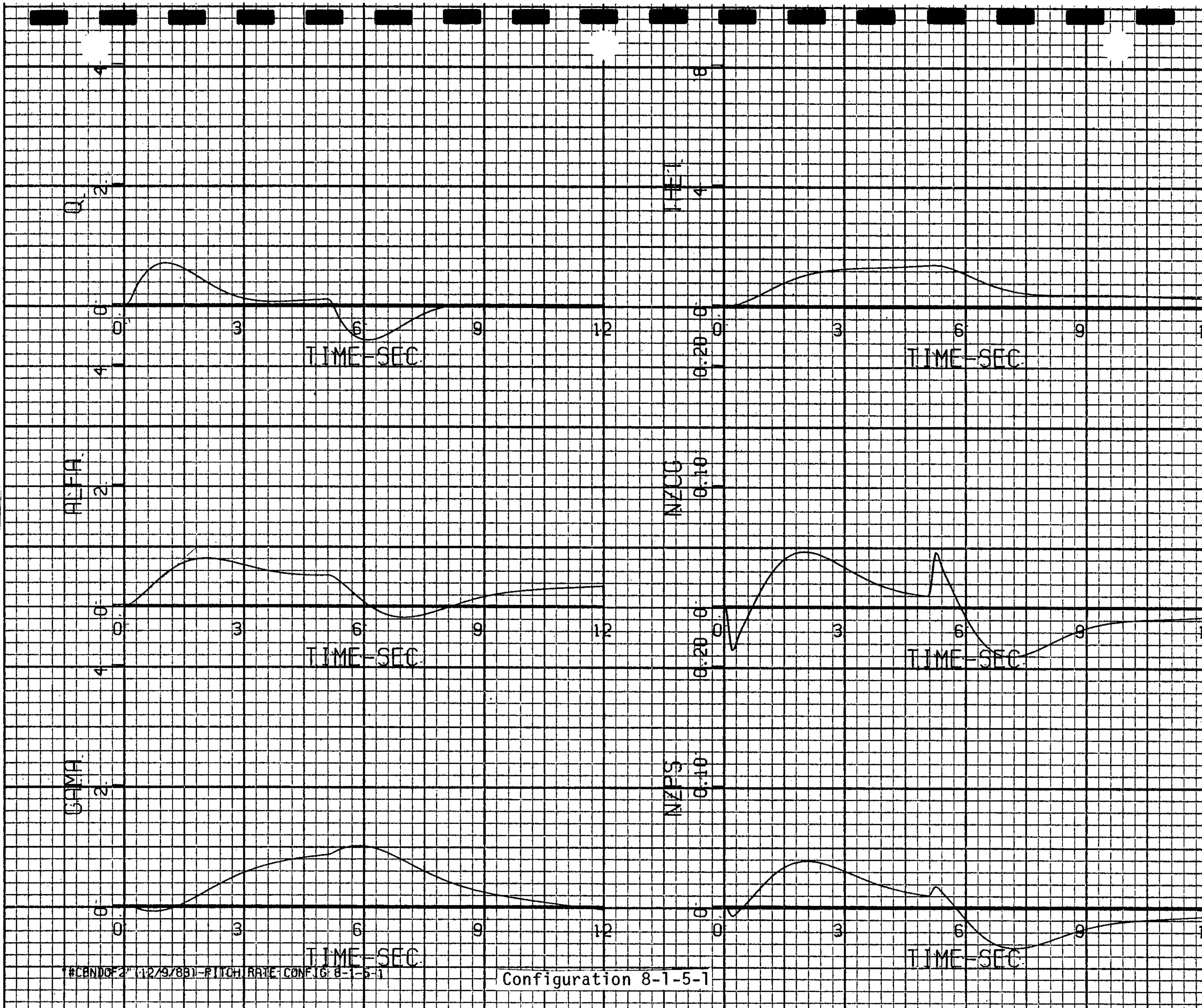


Configuration 8-1-5



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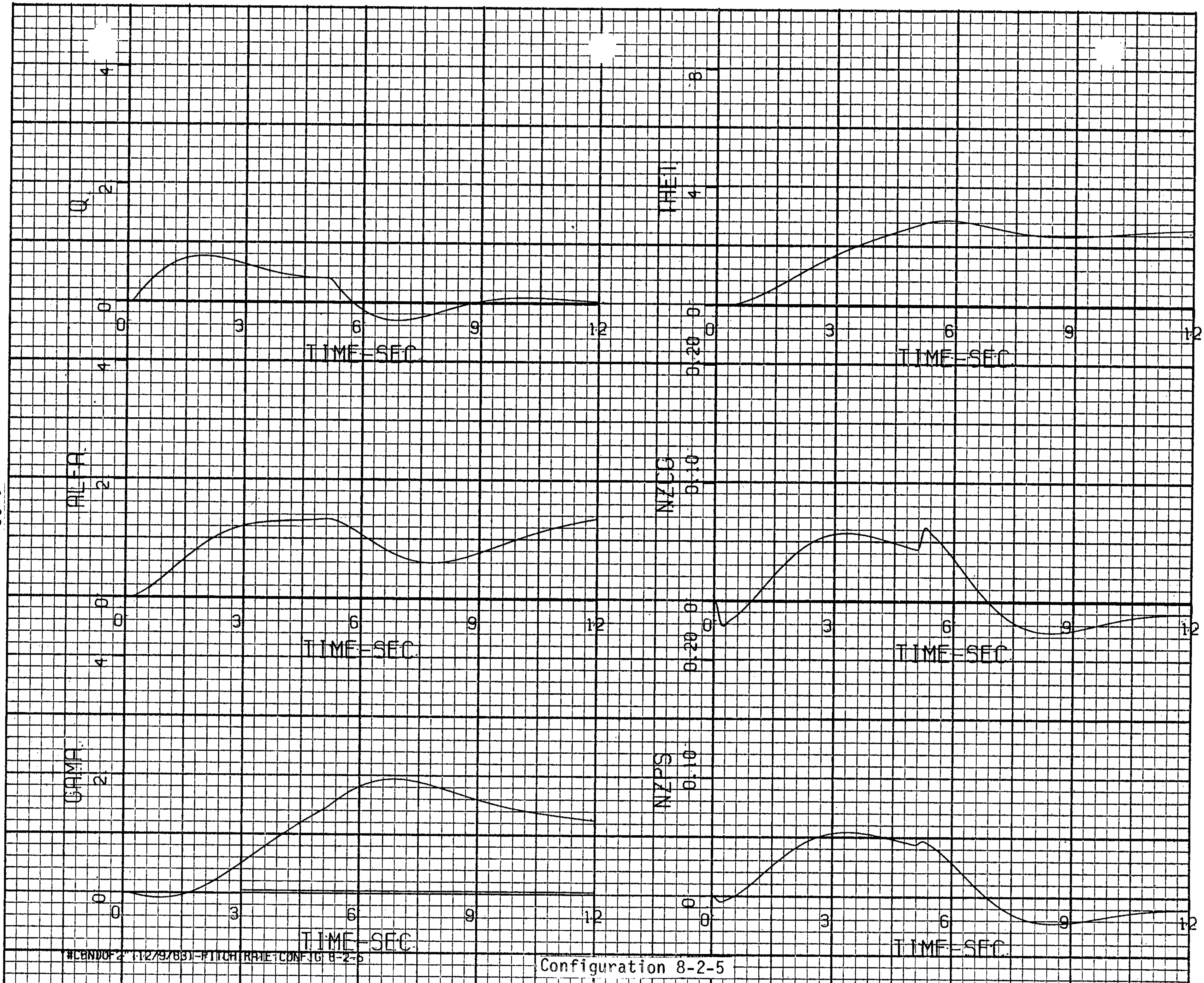

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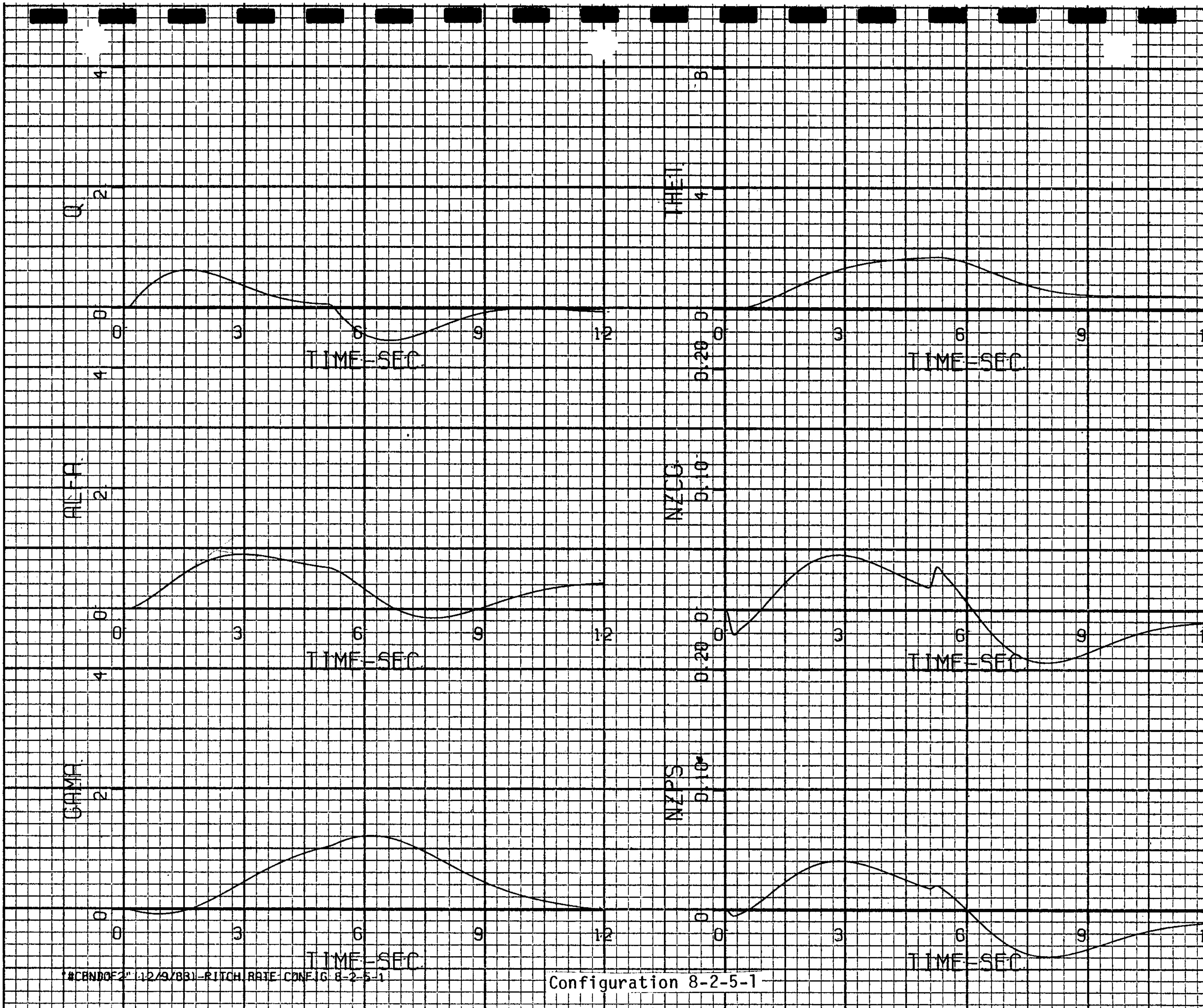

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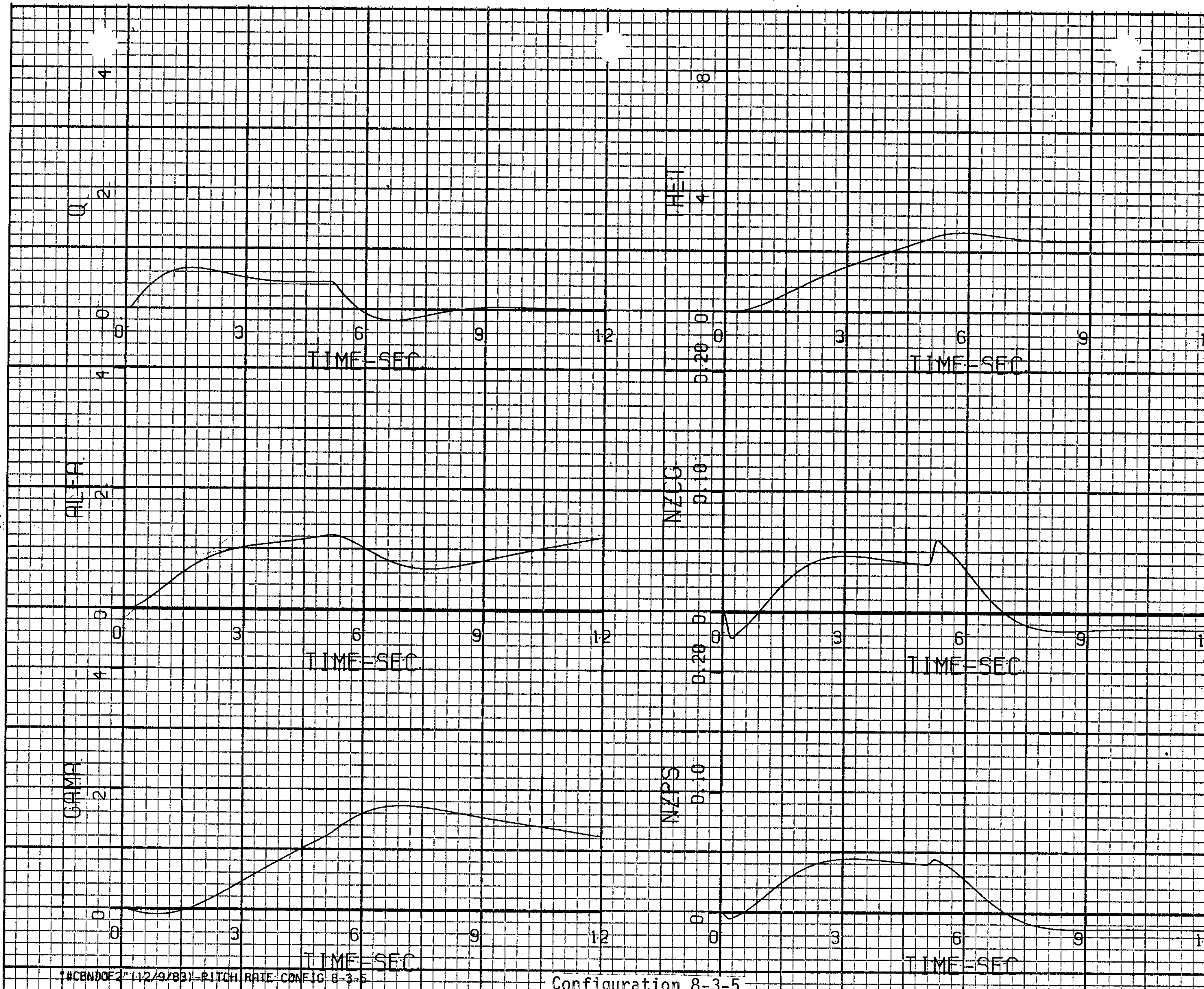

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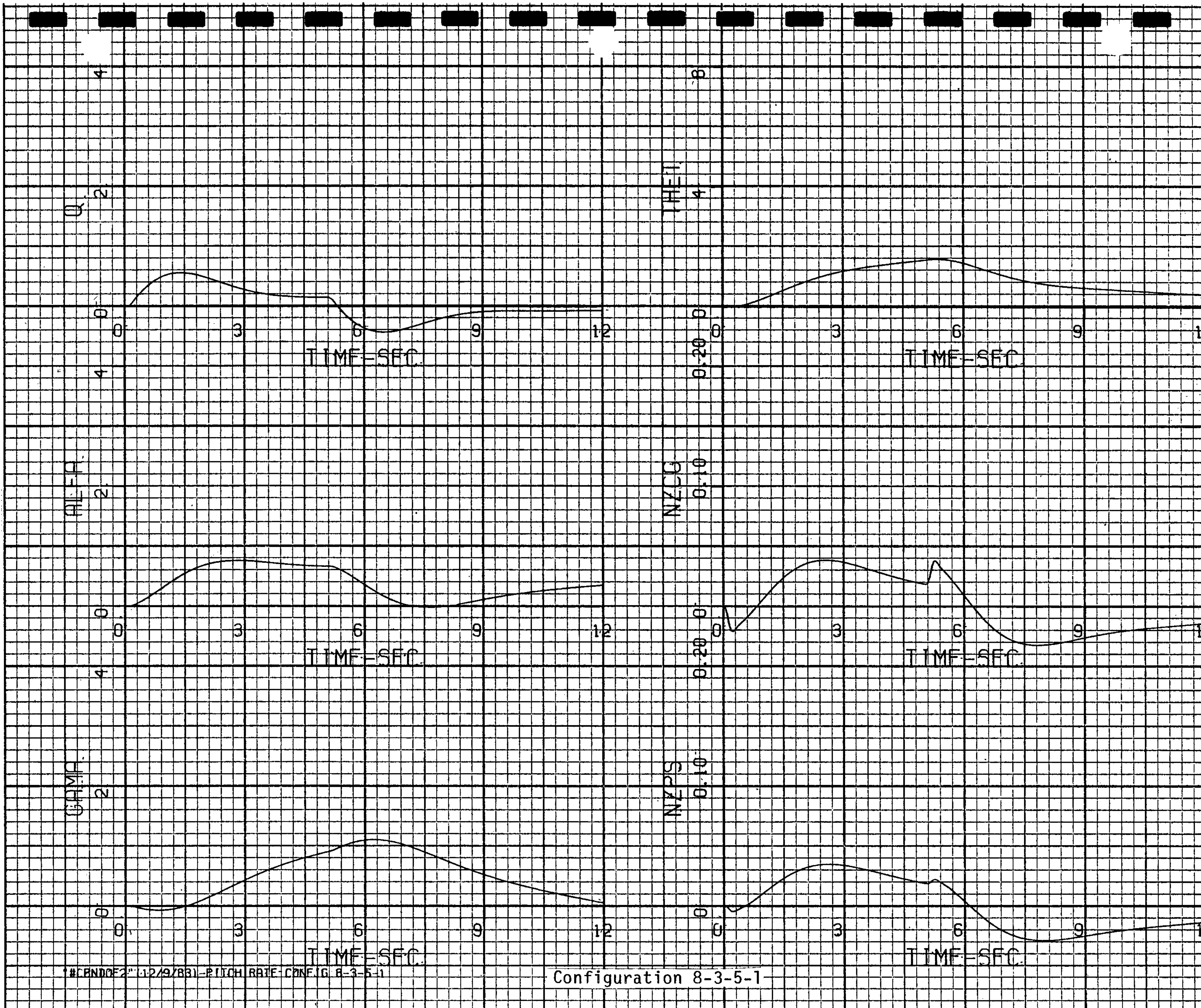

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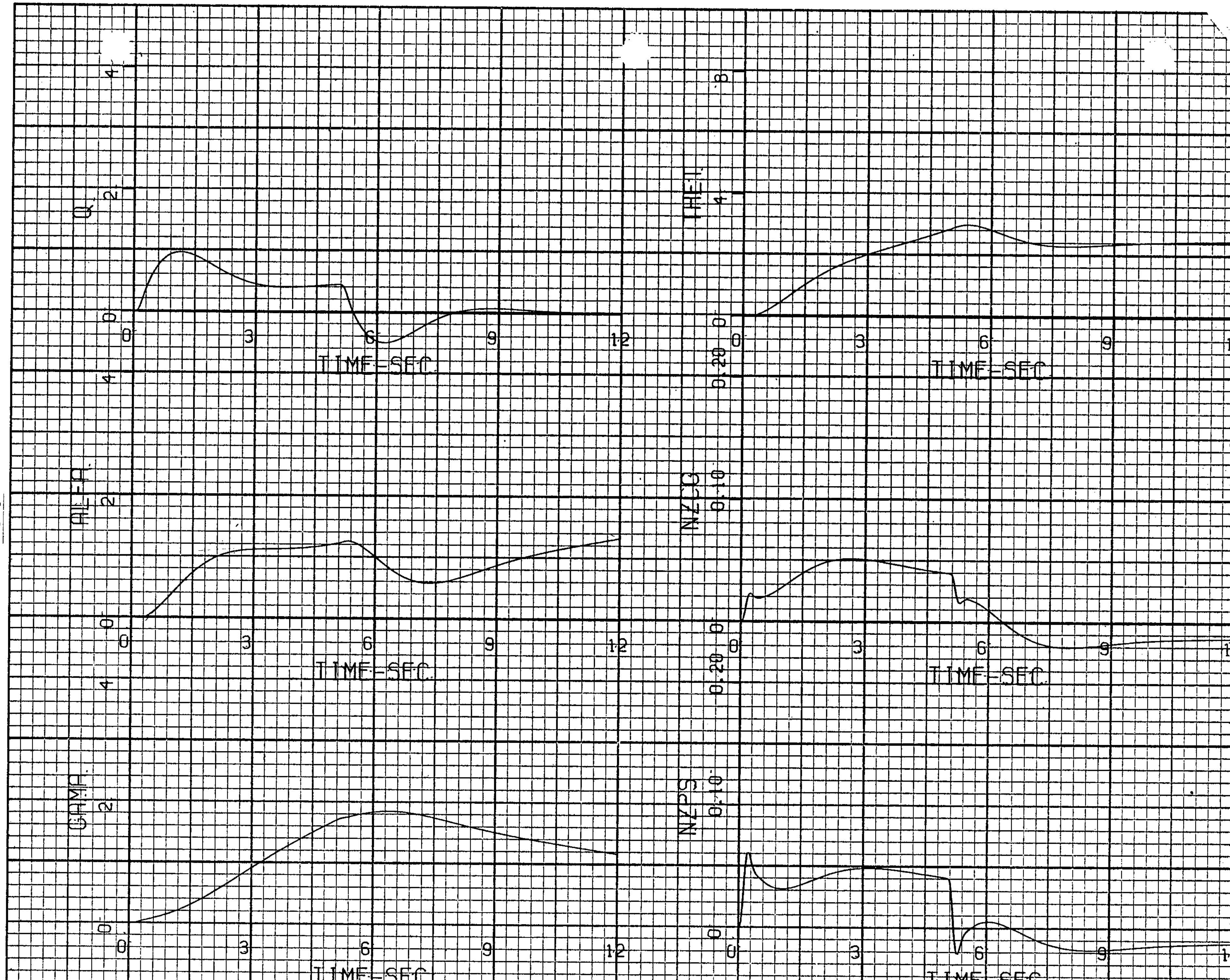
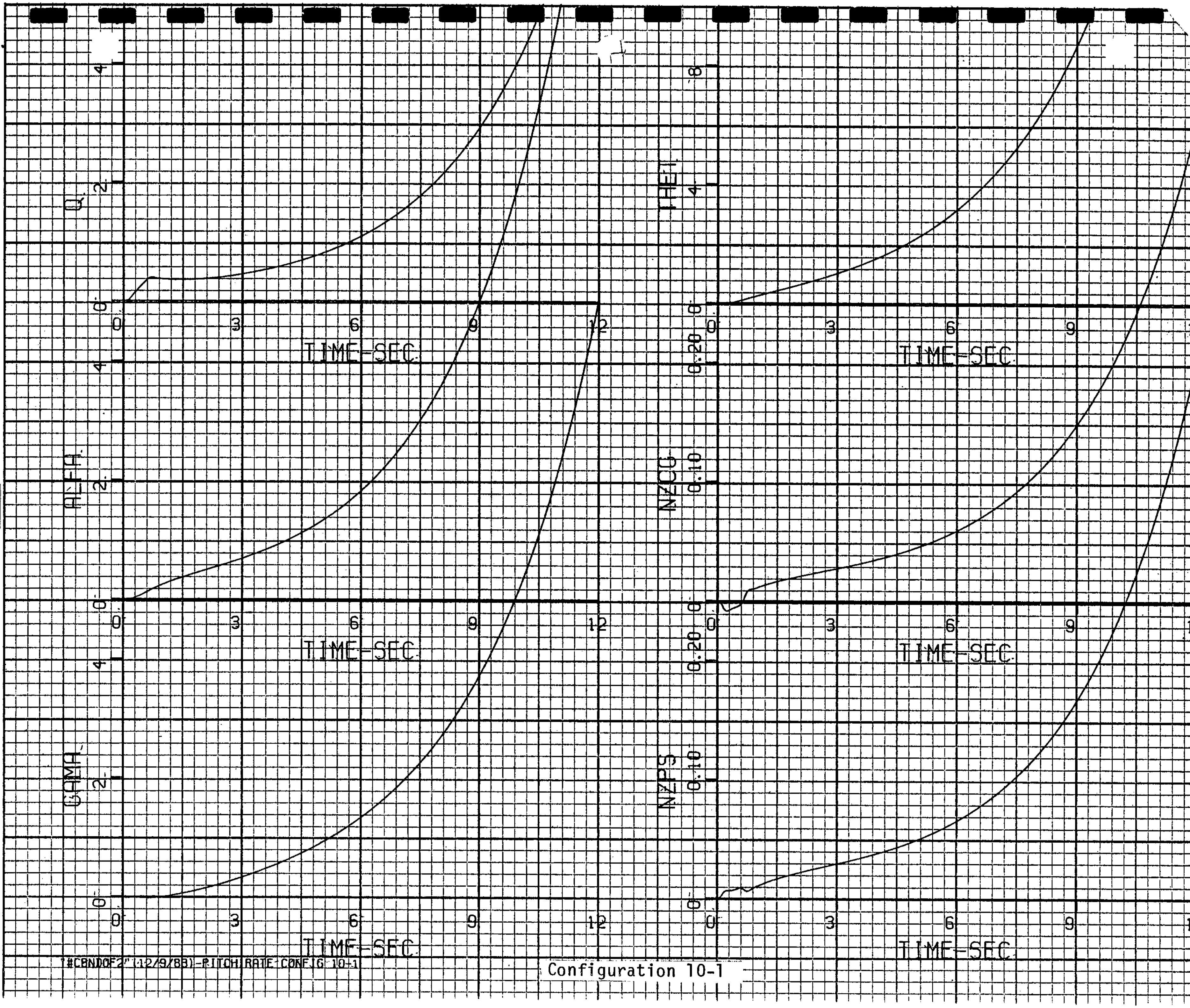


"#CBNDOF2" (12/9/83) PITCH RATE CONFIG 8-4-6

Configuration 8-4-6

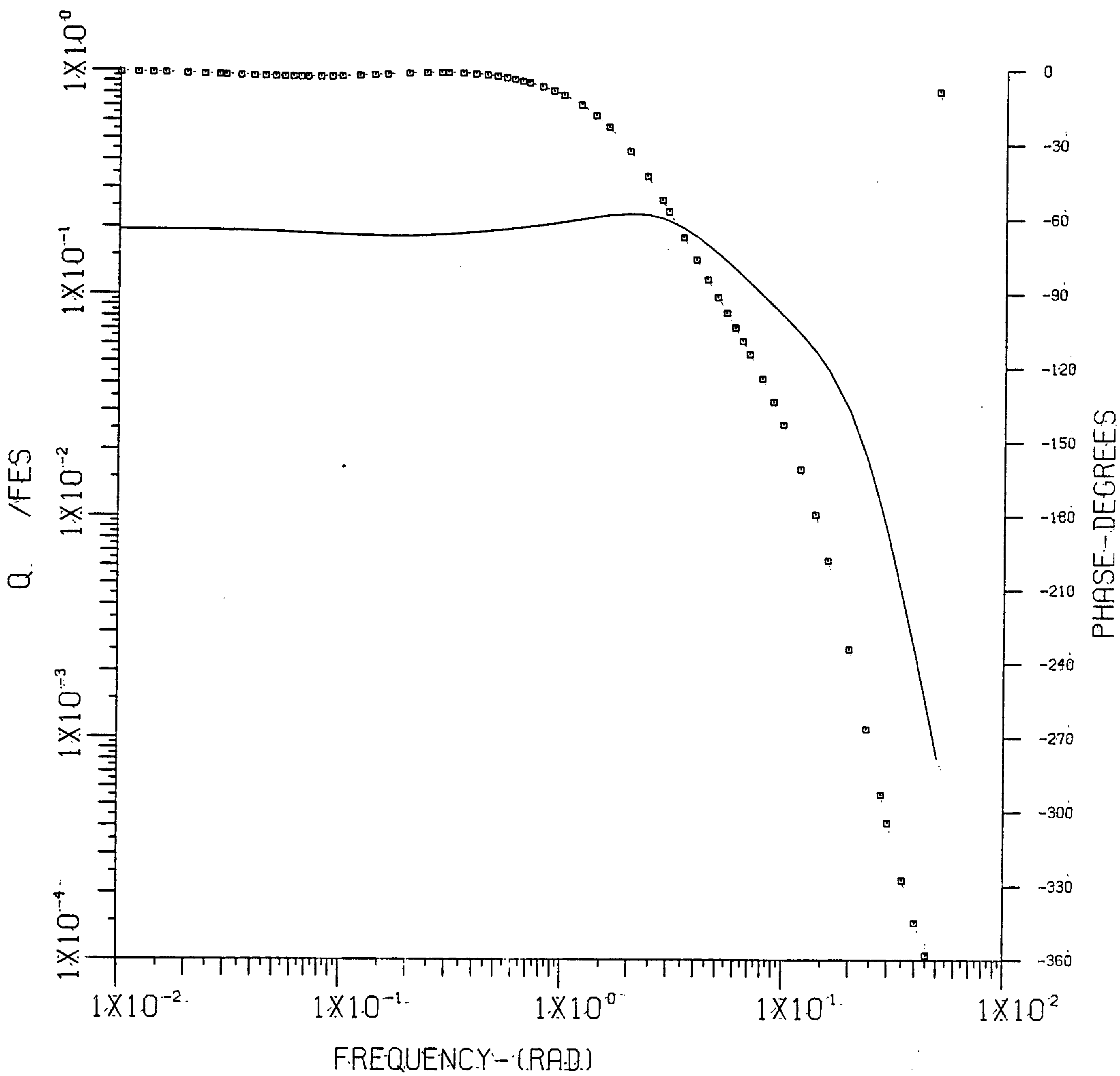


Configuration 10-1

APPENDIX B

COMPUTER BODE PLOTS

Configuration 1-1-1



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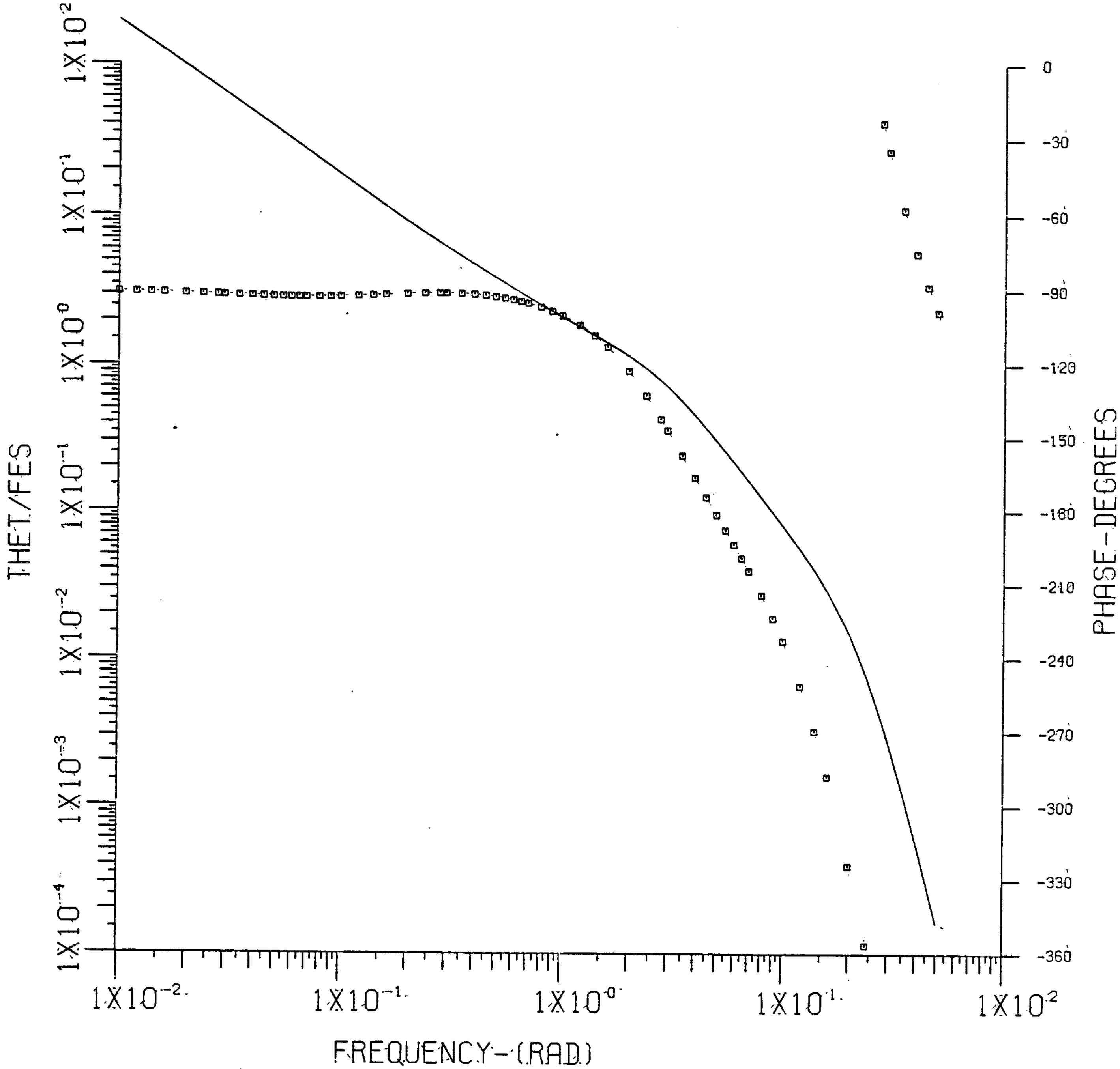

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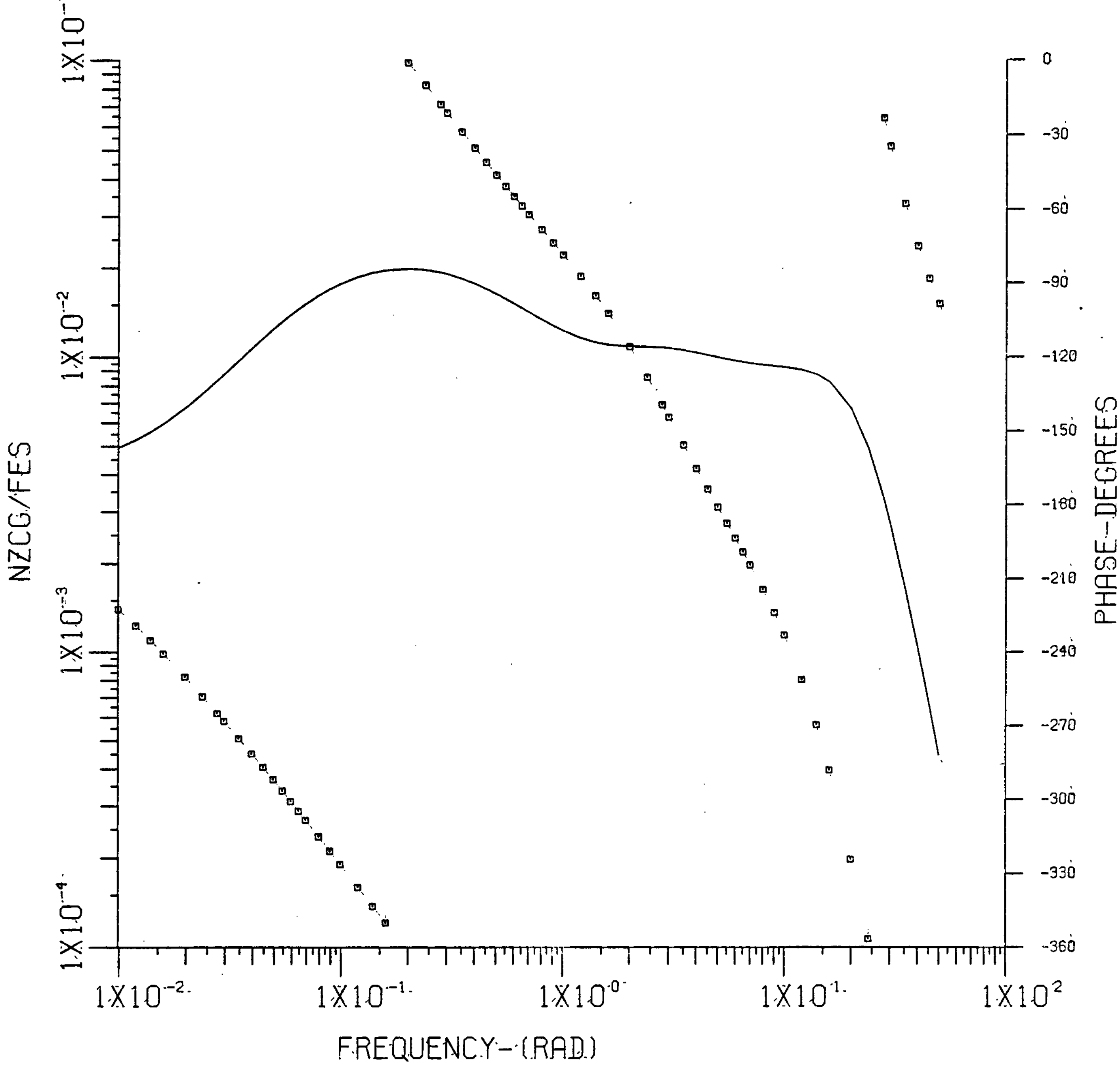

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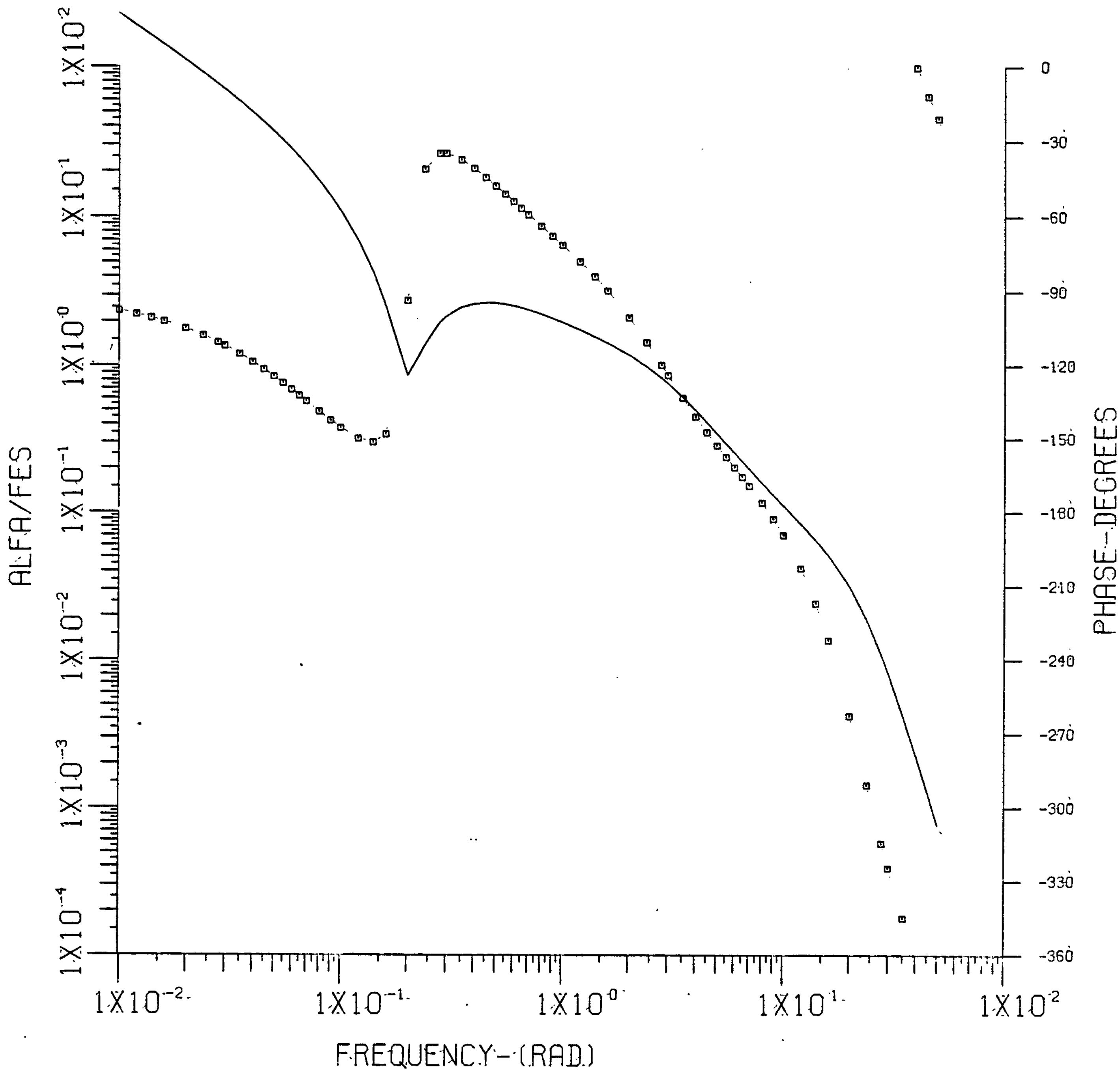

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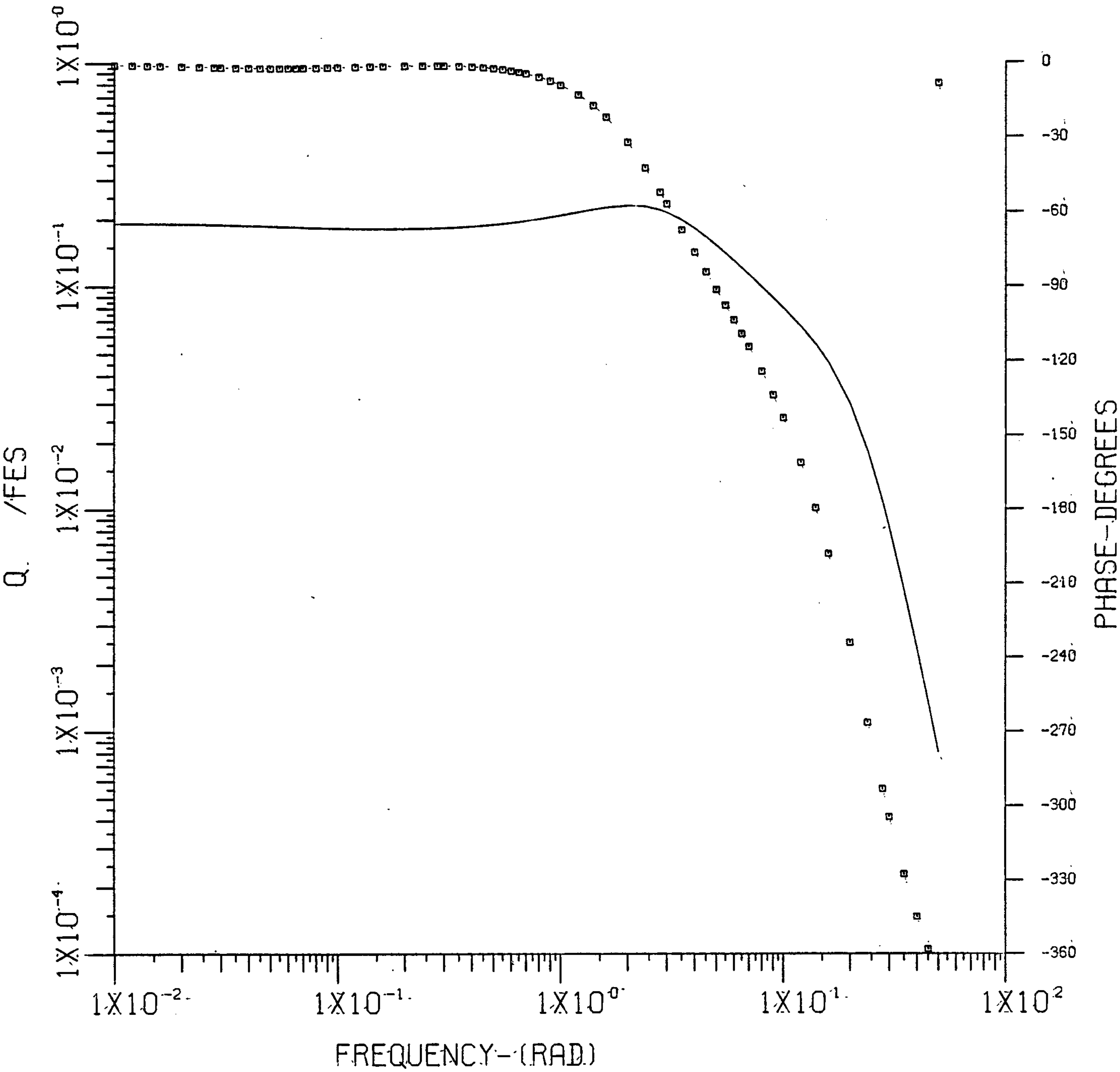

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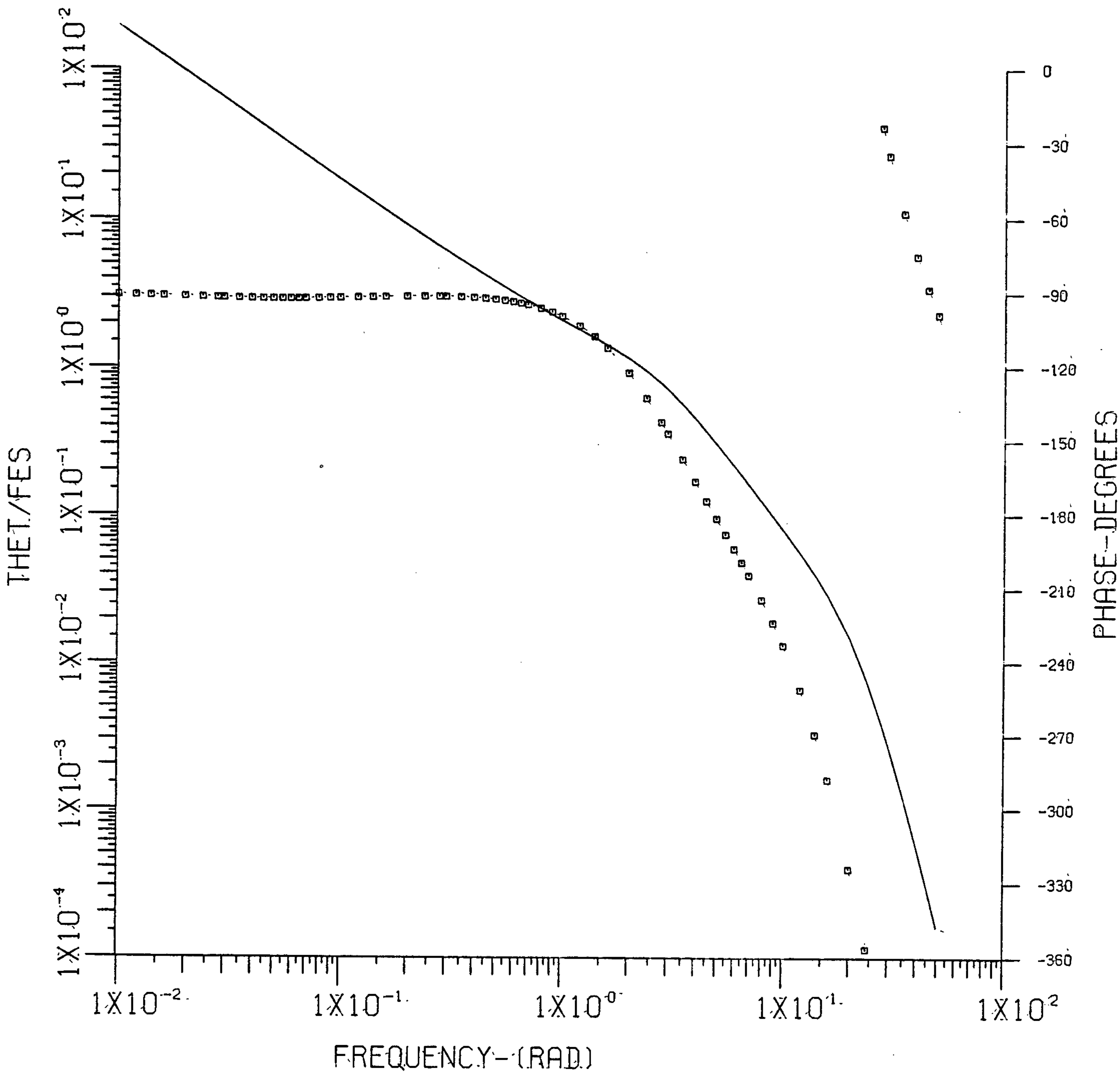

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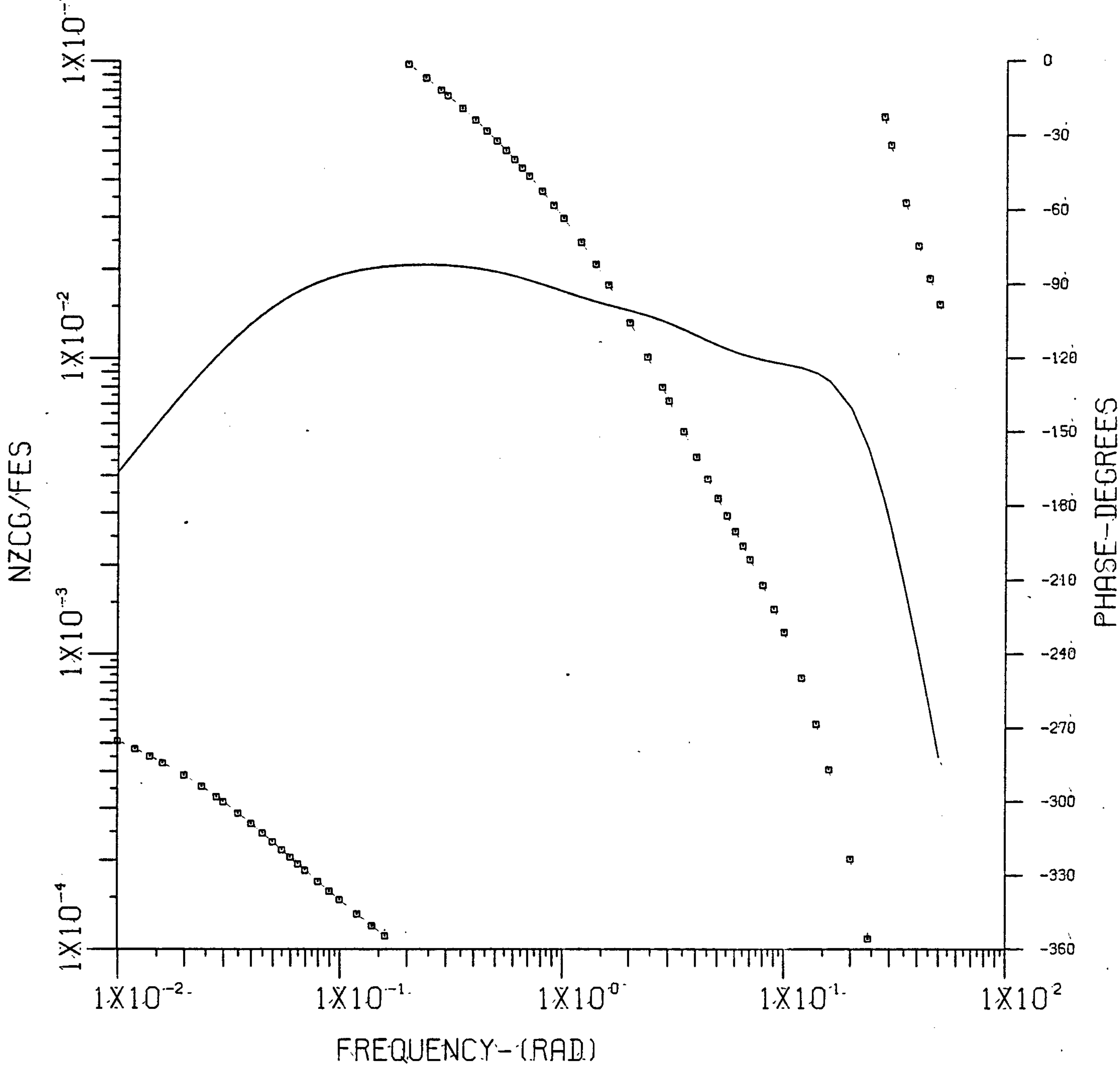

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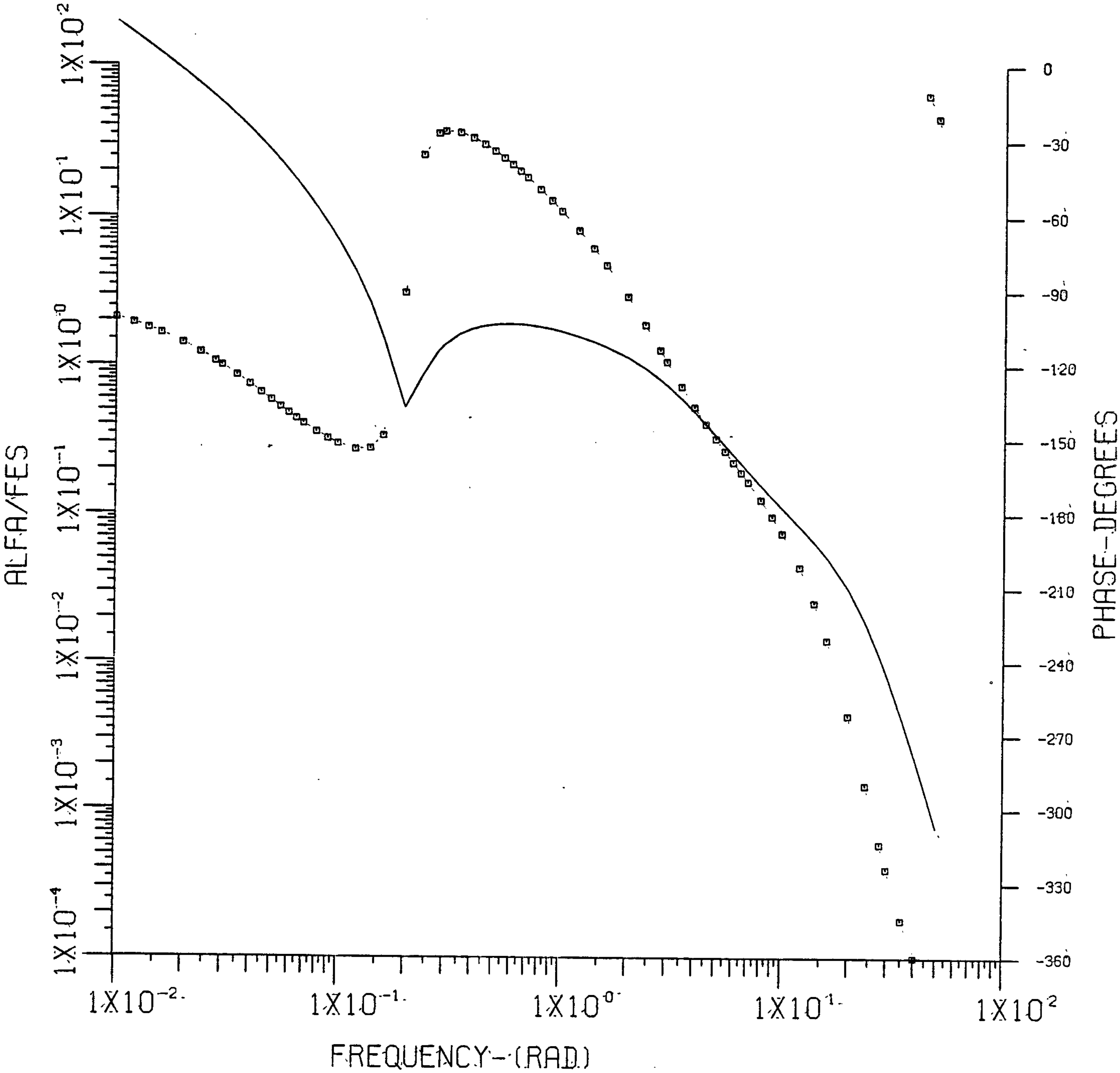

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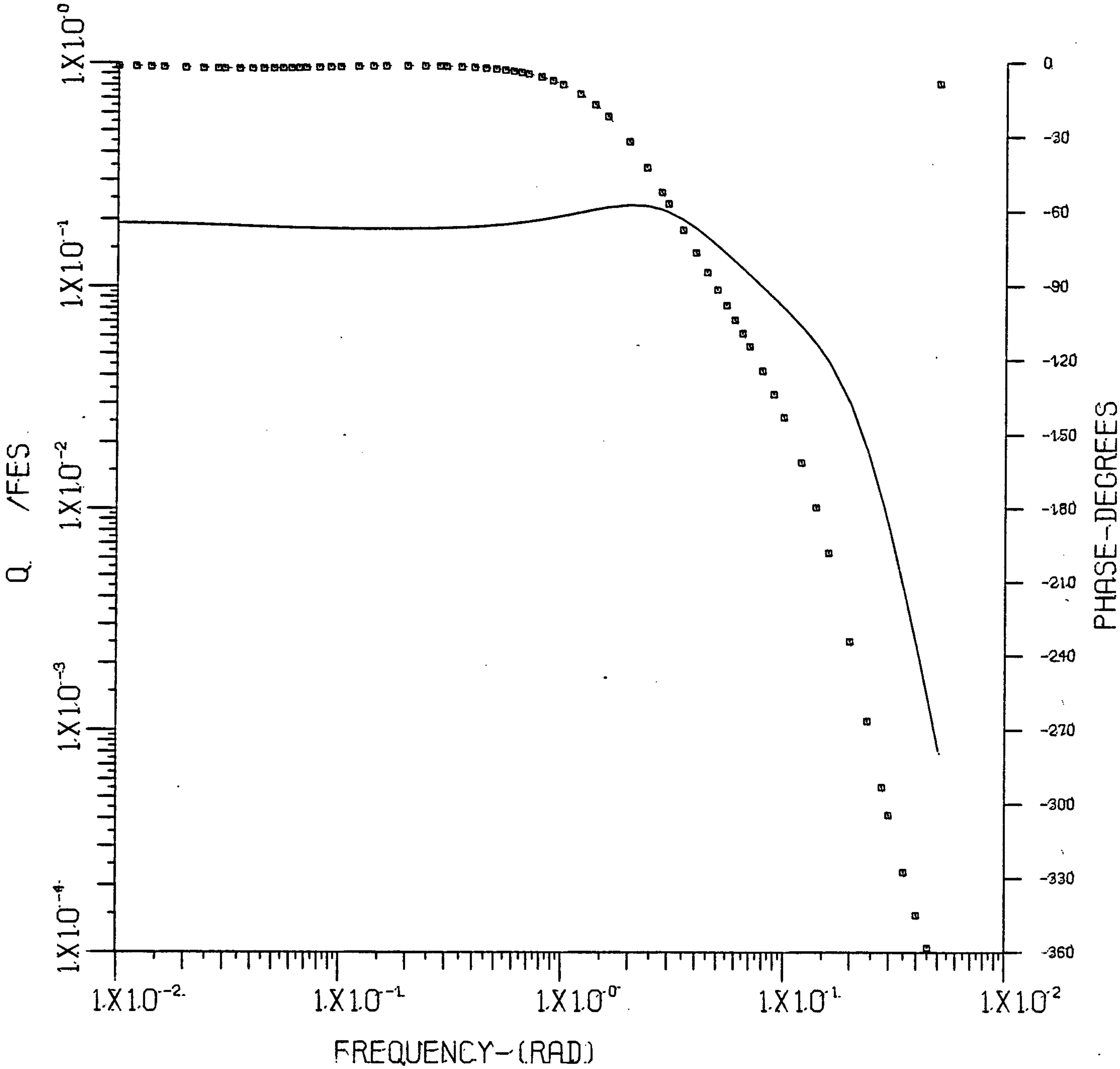

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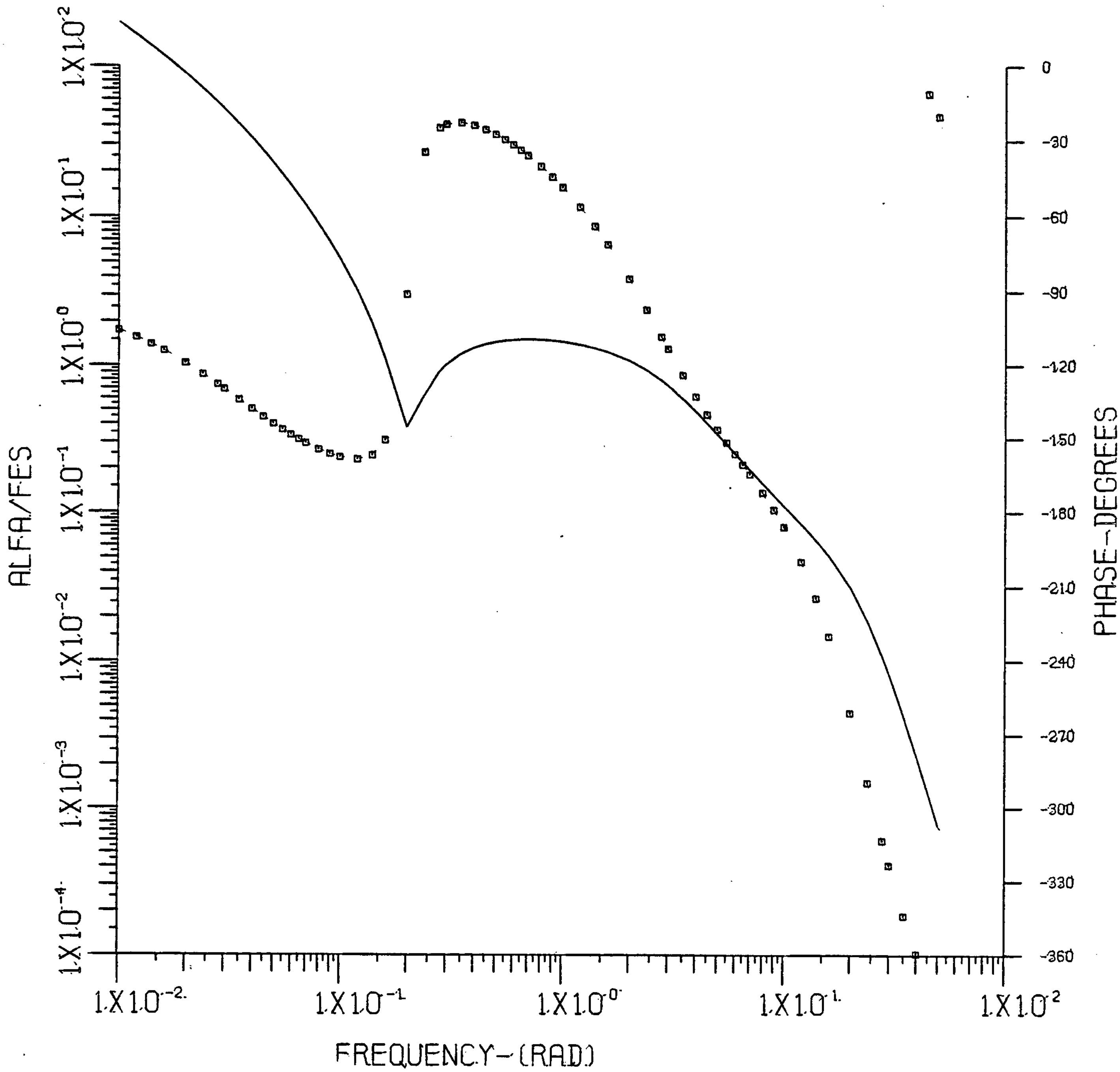

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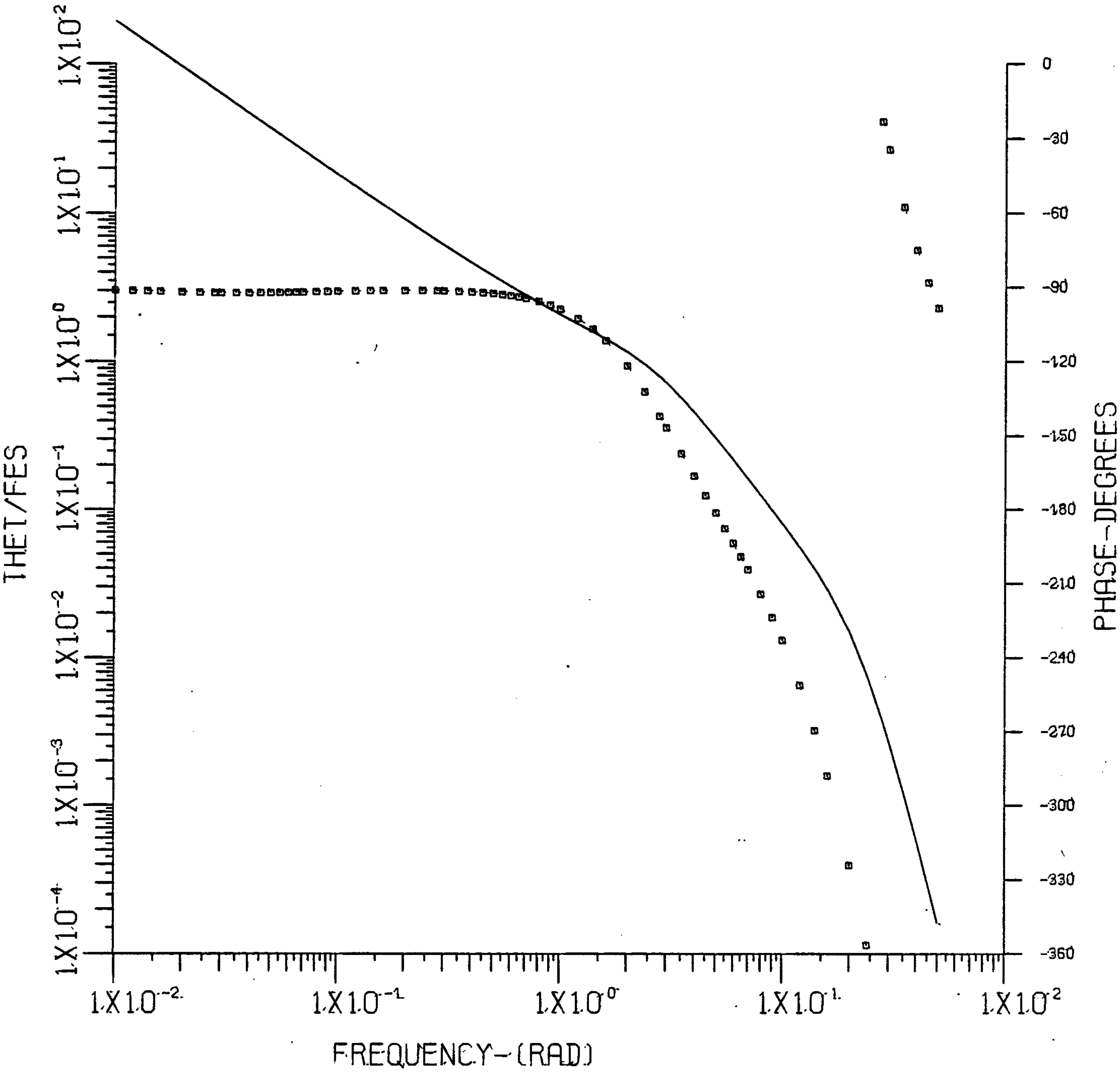

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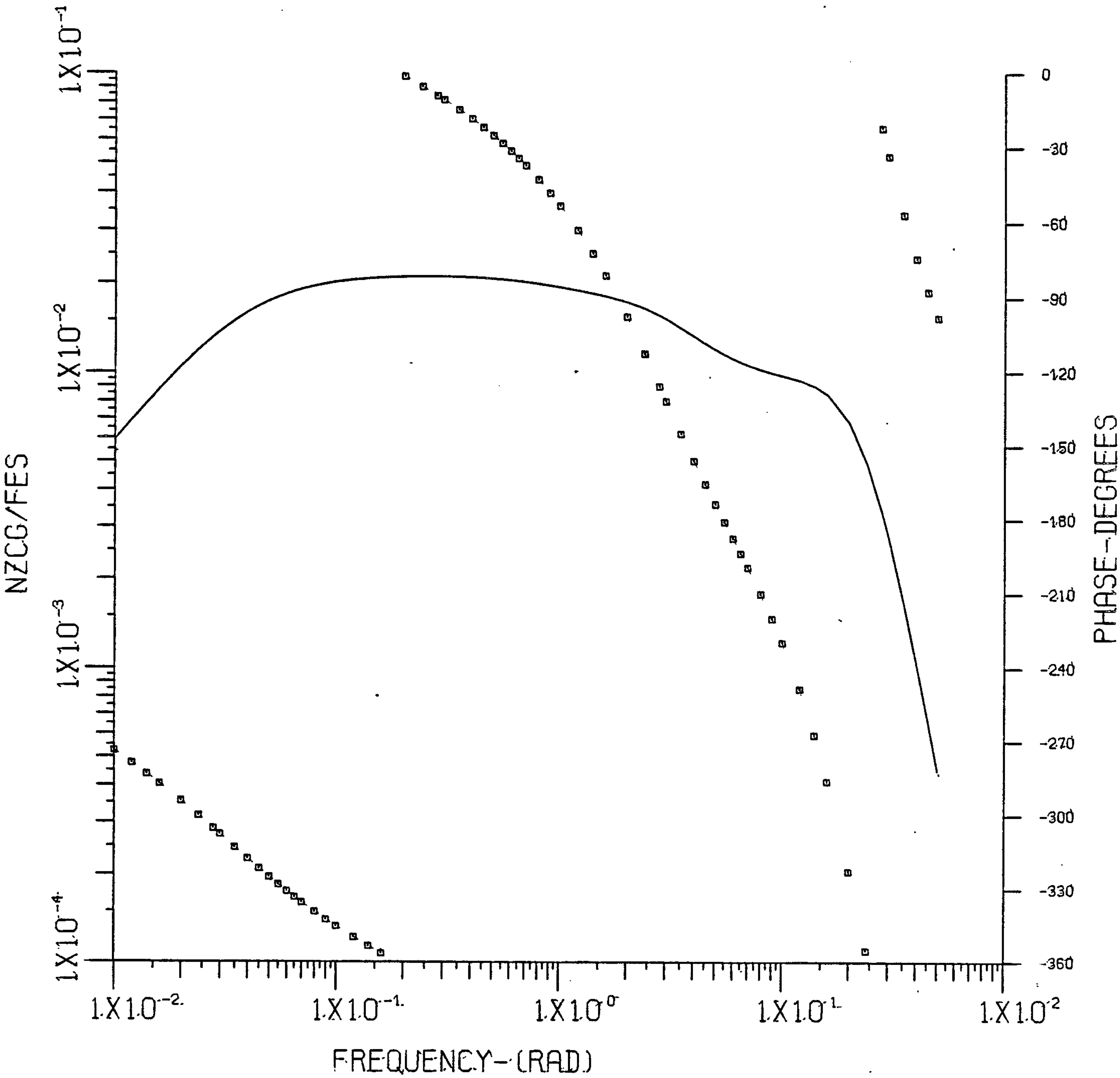

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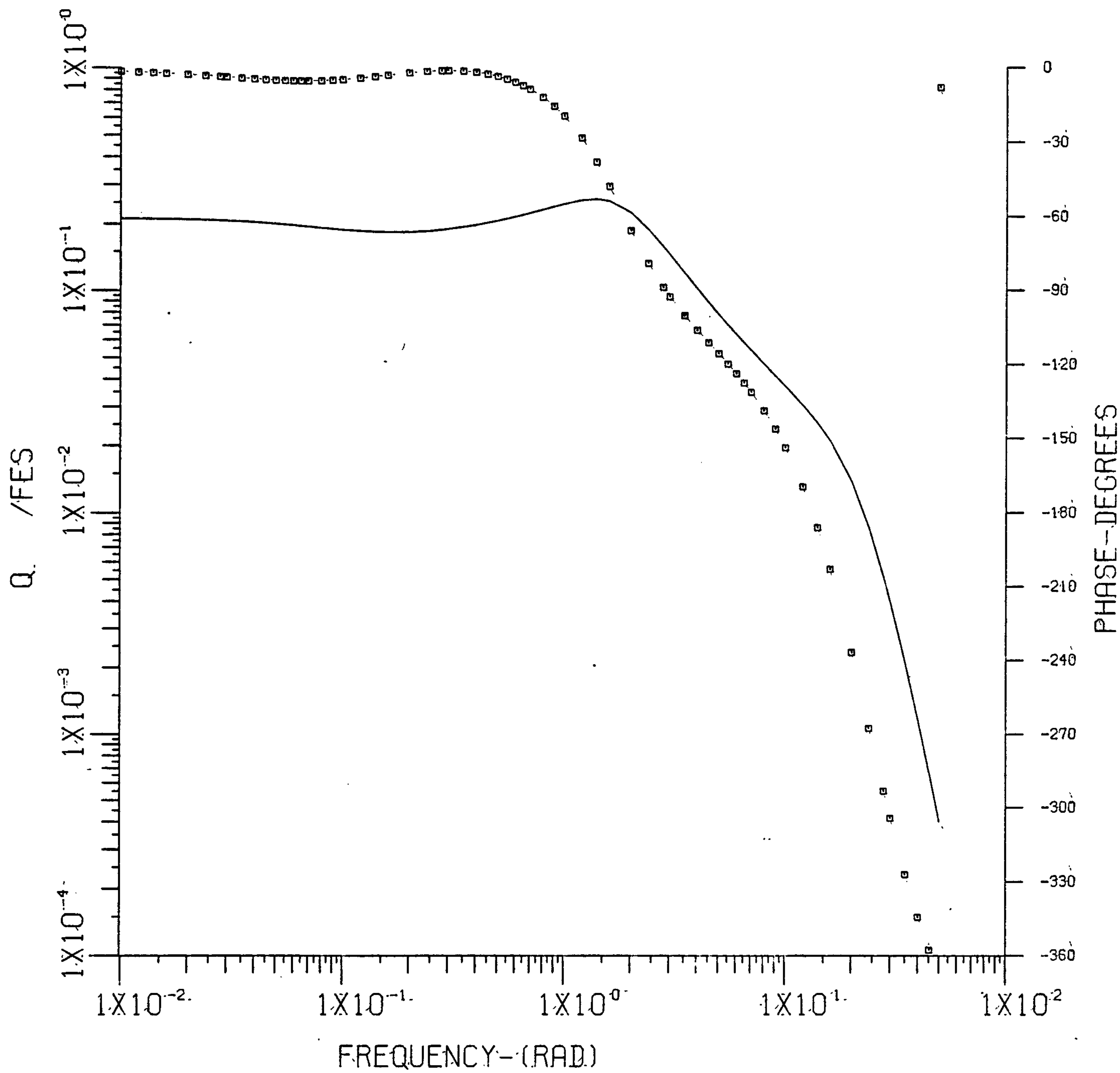

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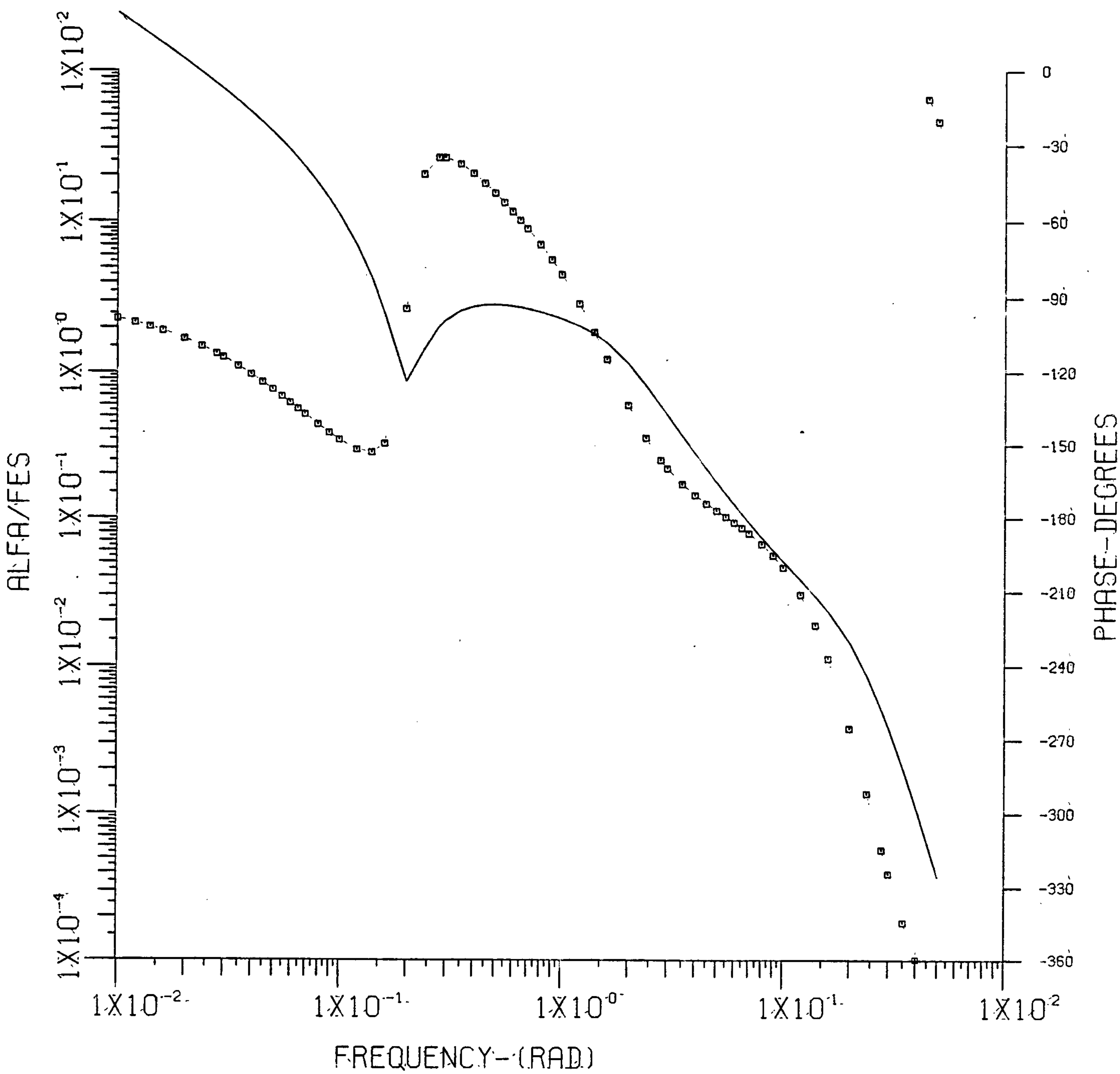

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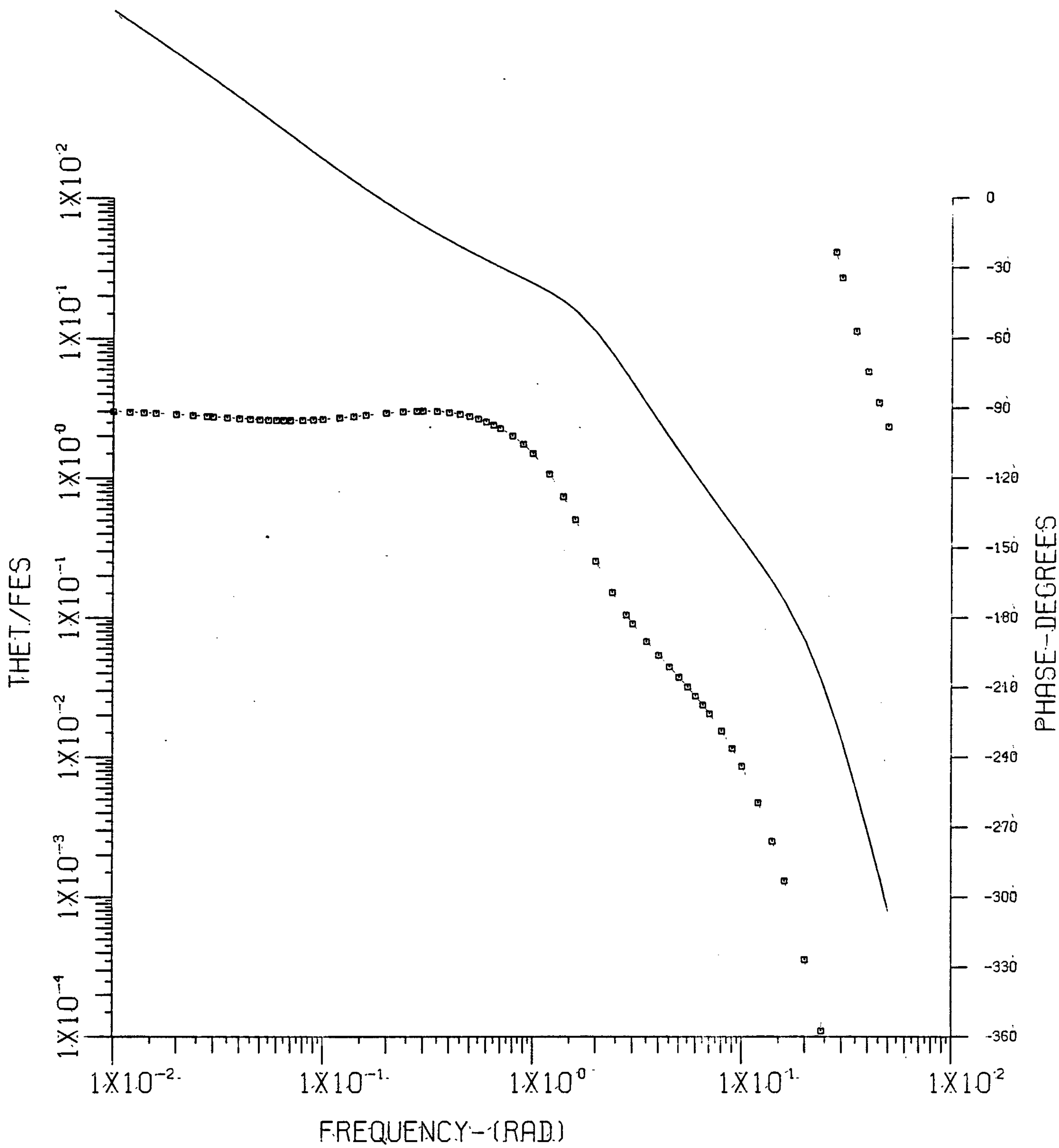

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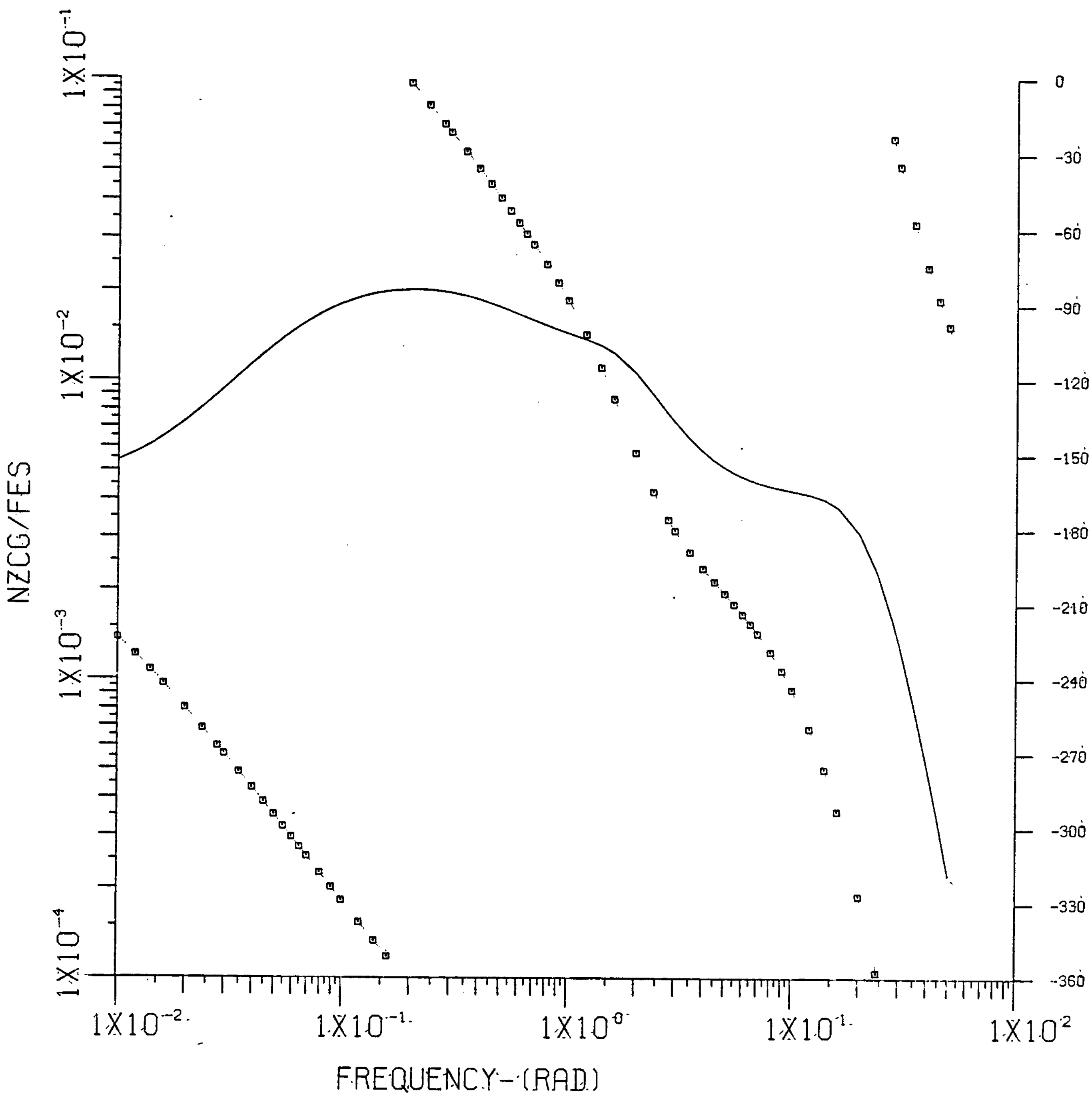

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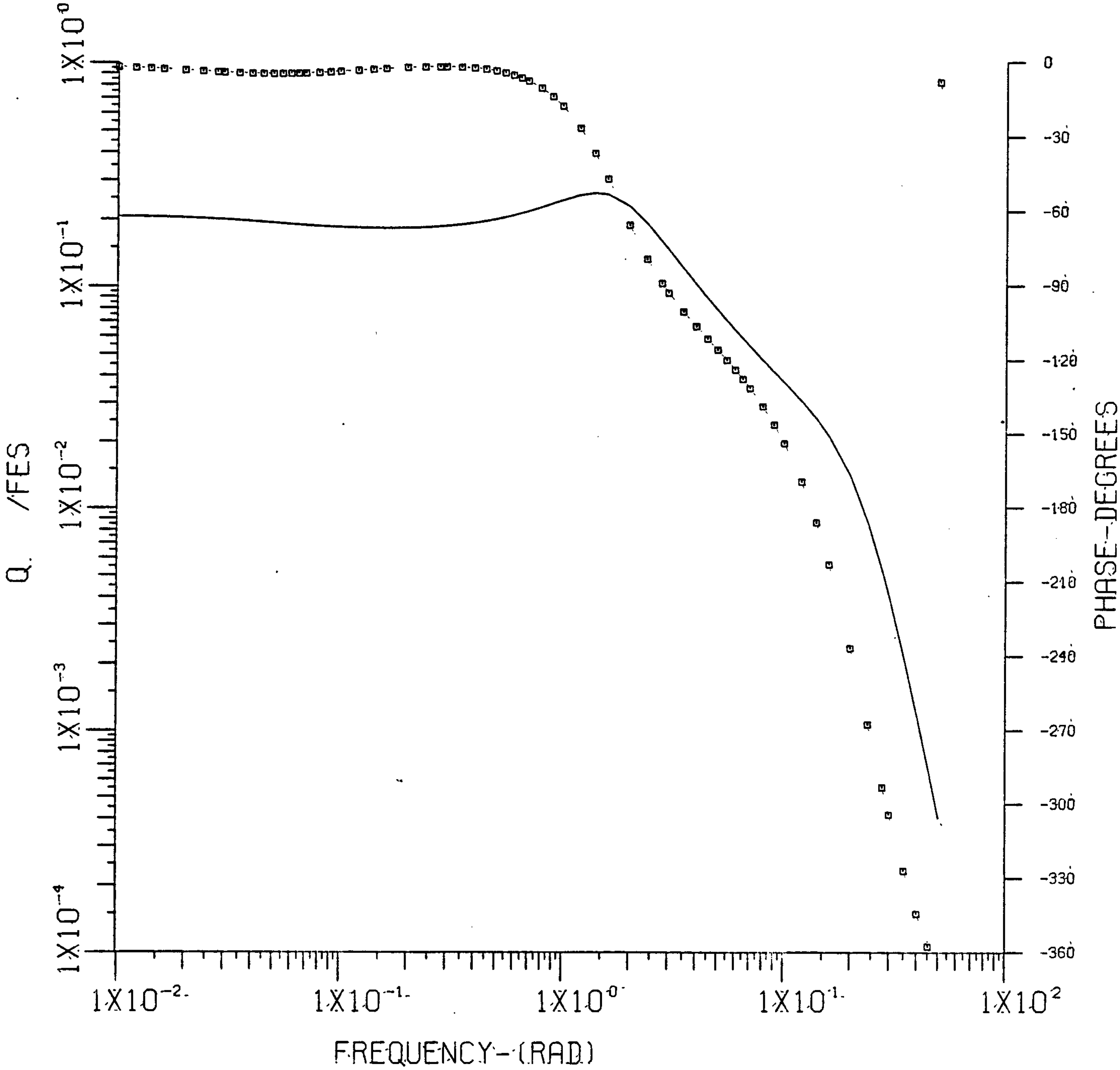

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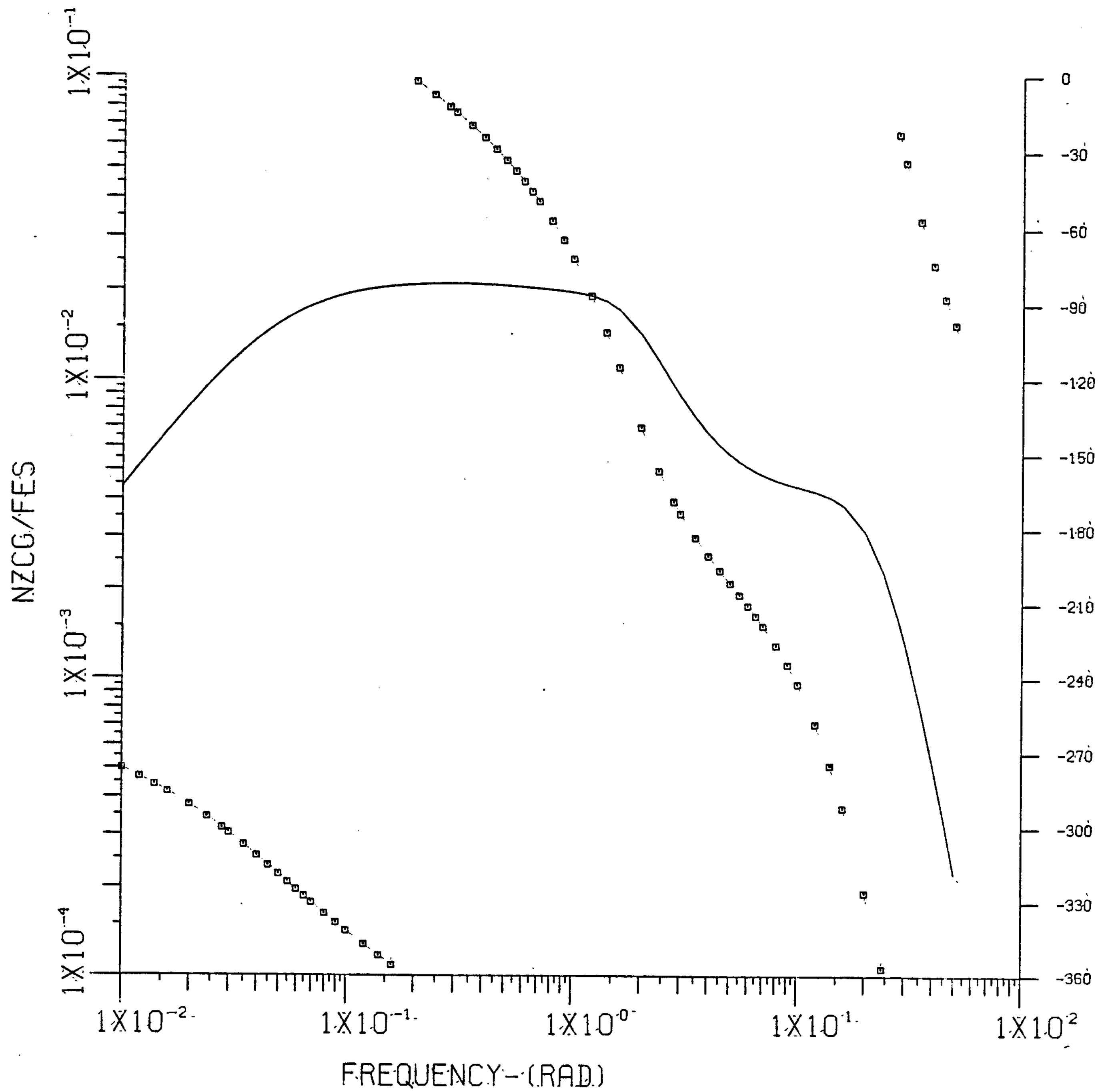

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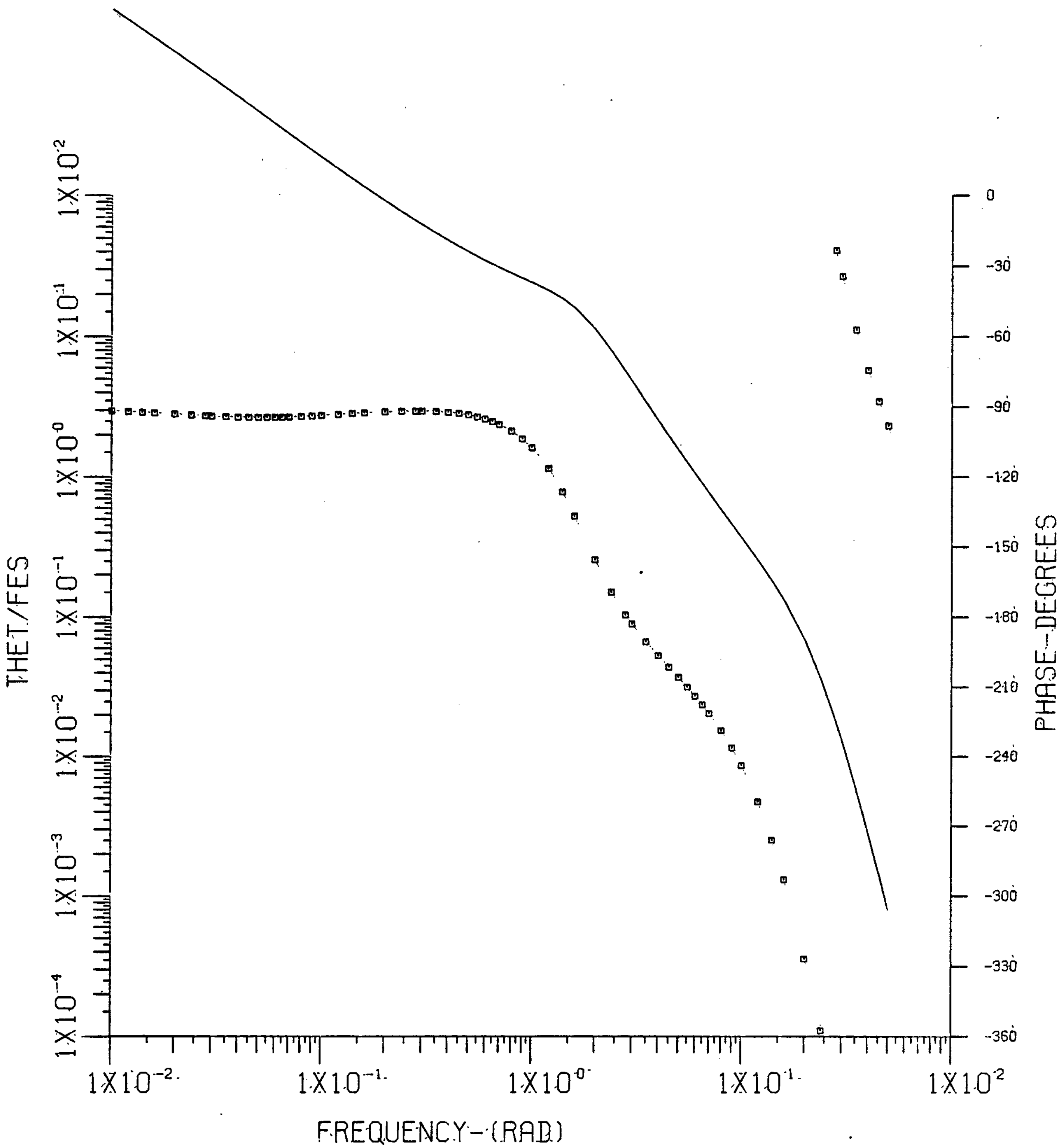

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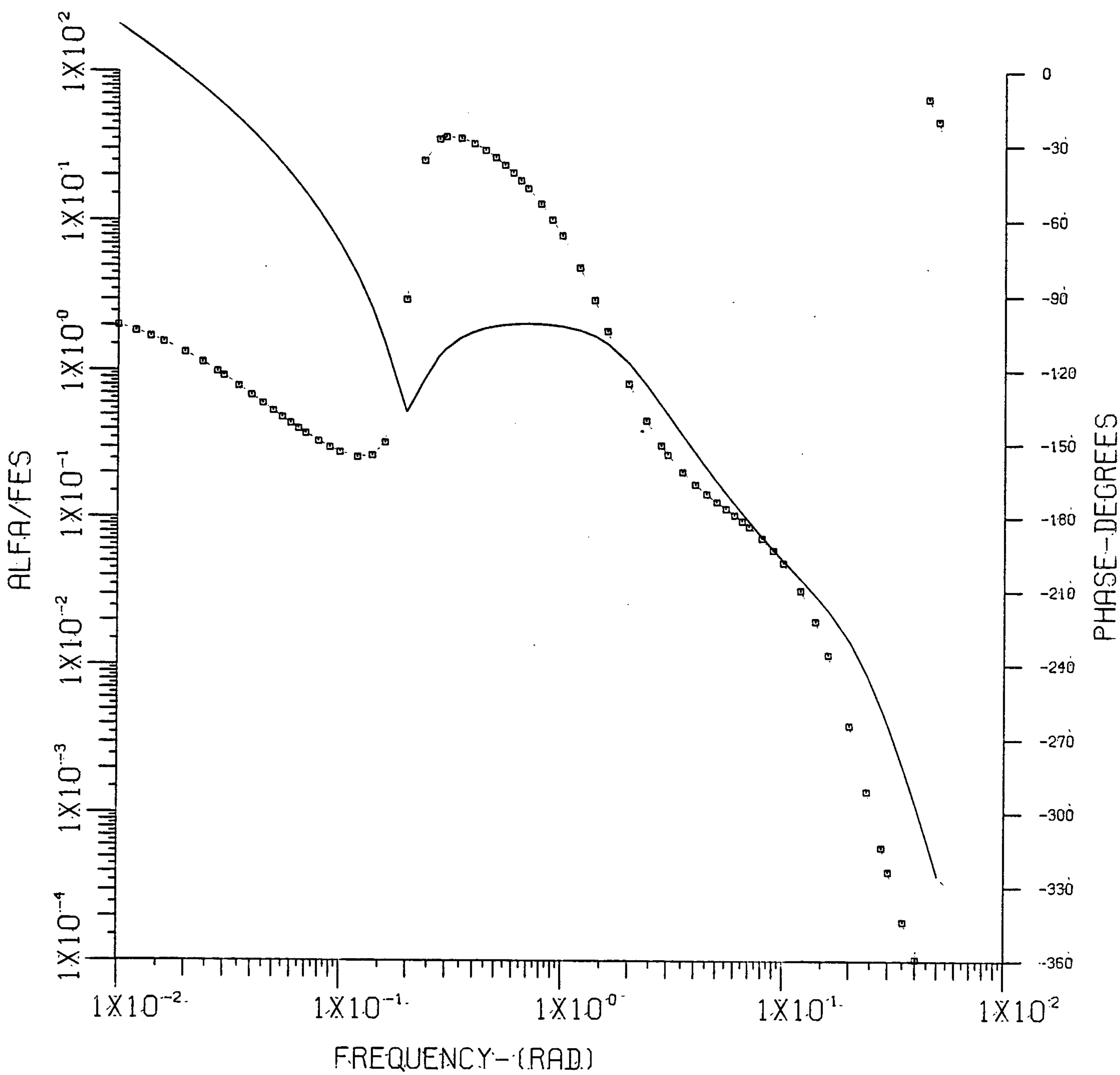

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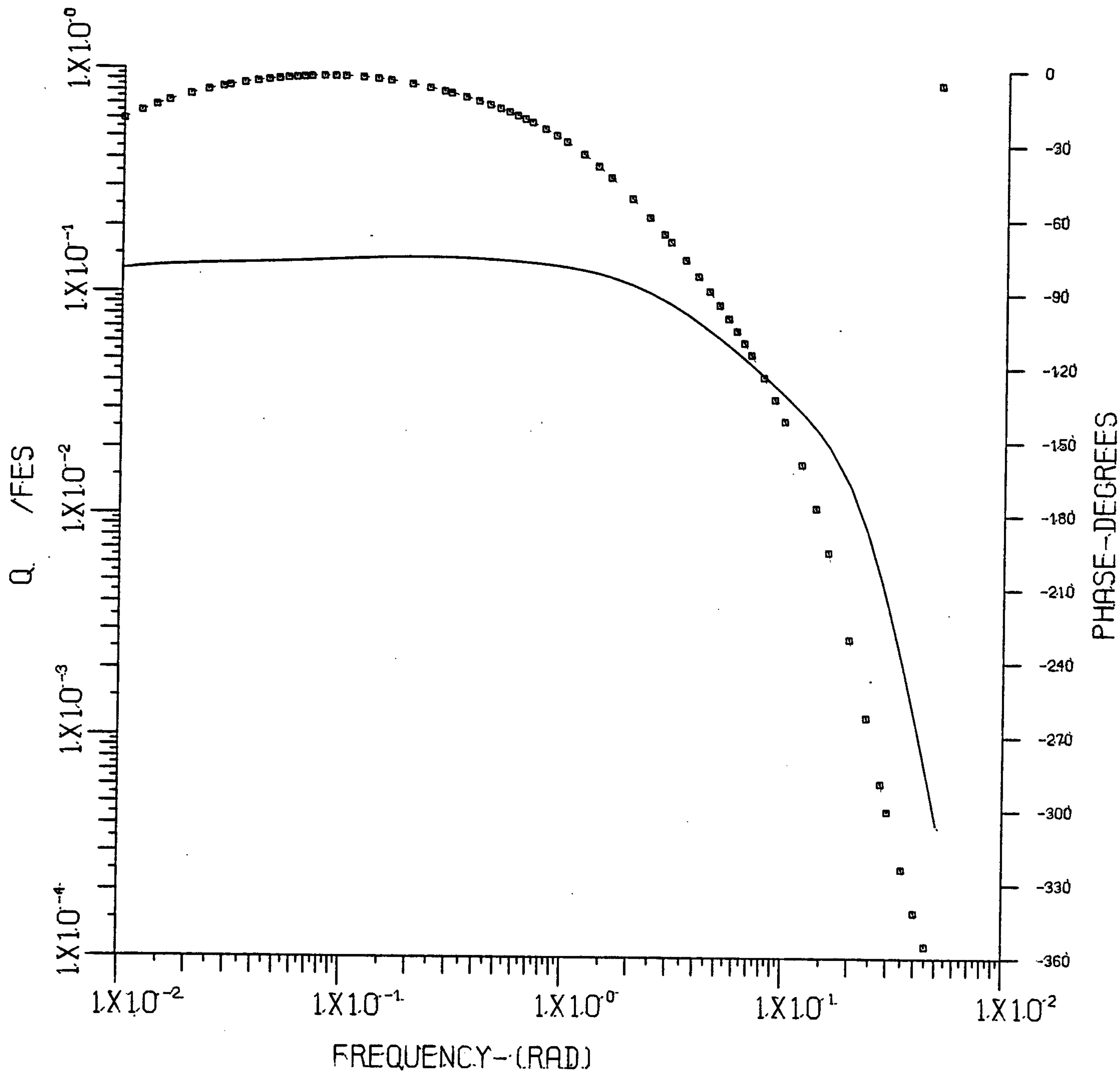

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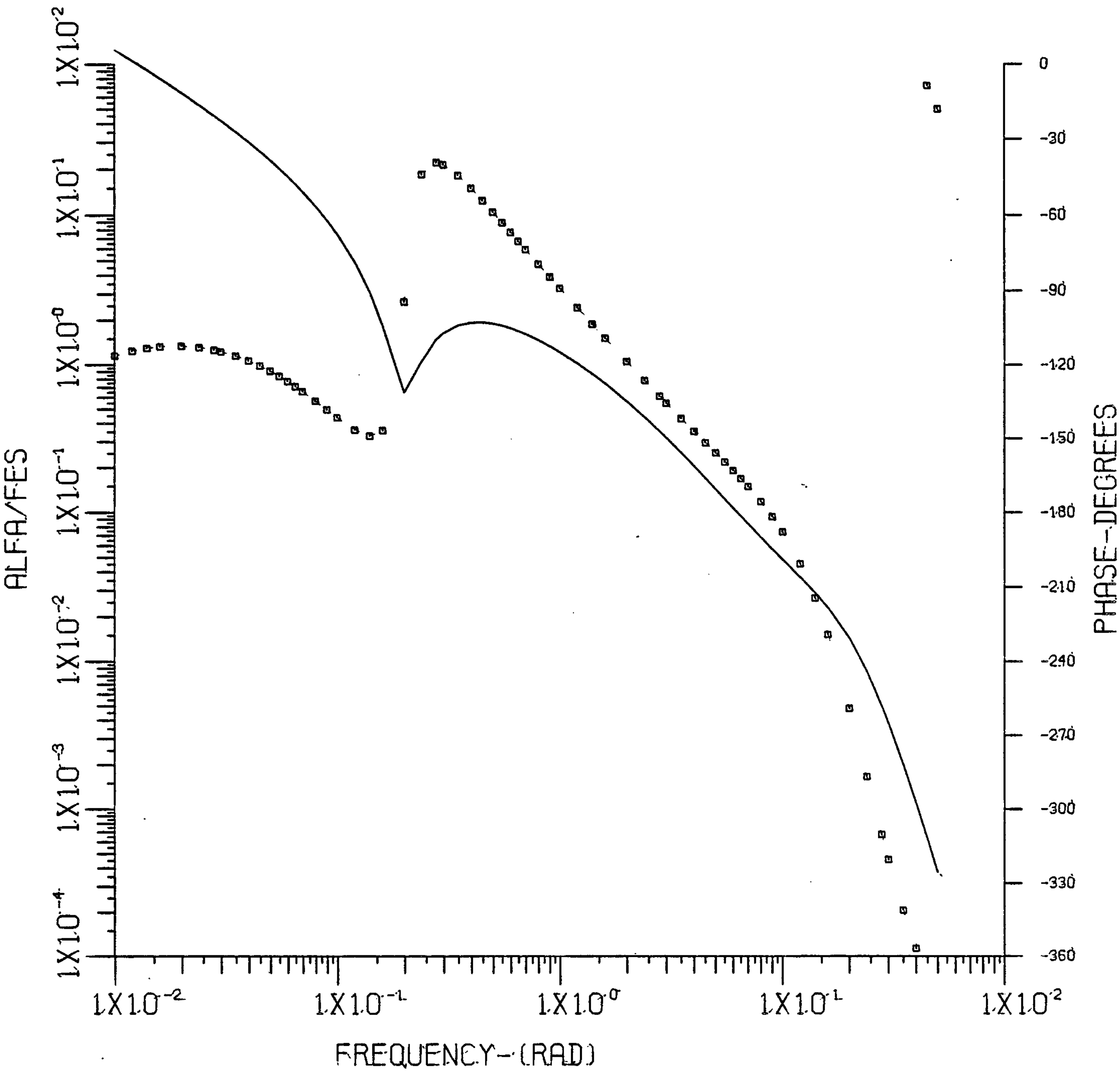

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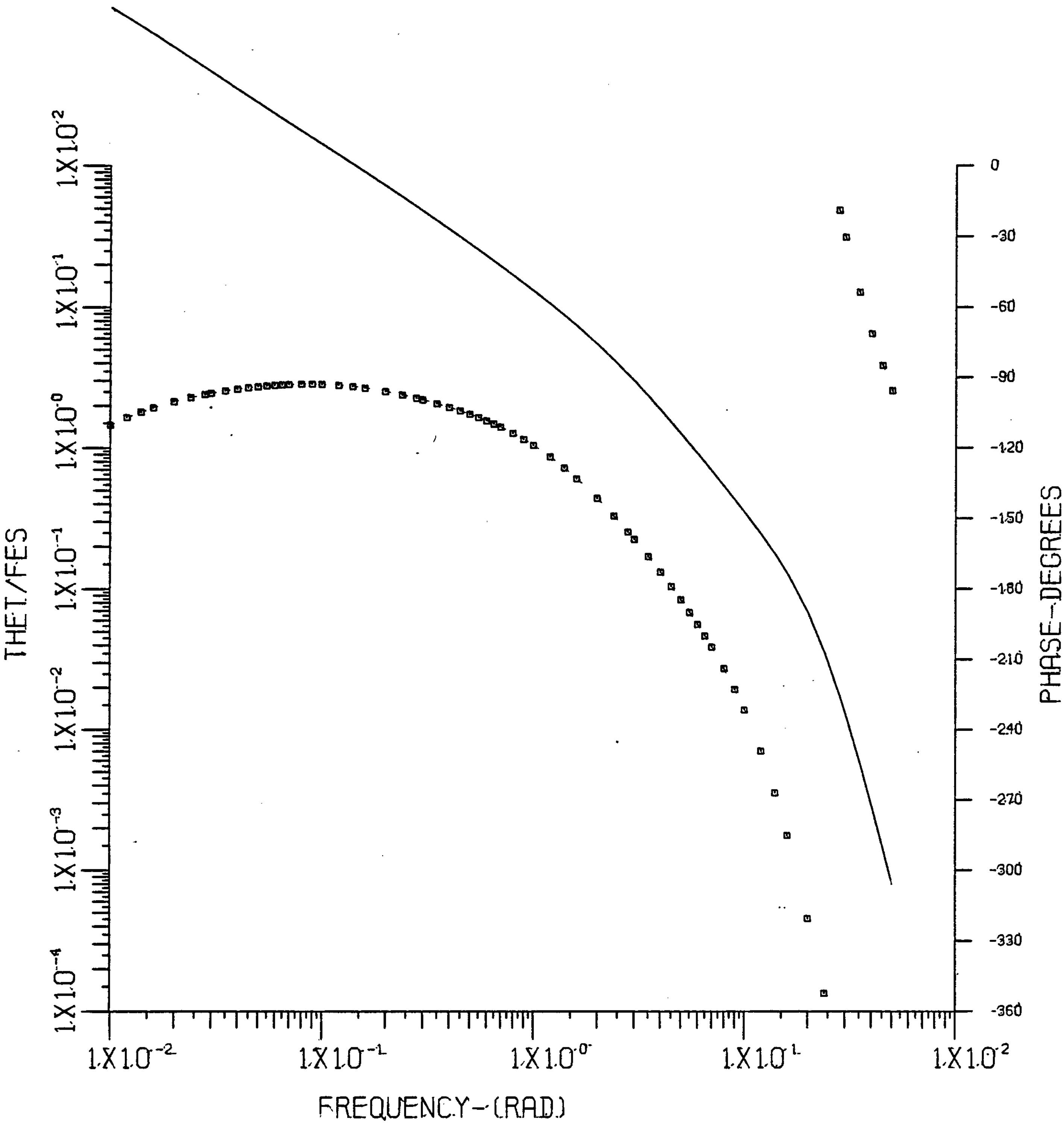

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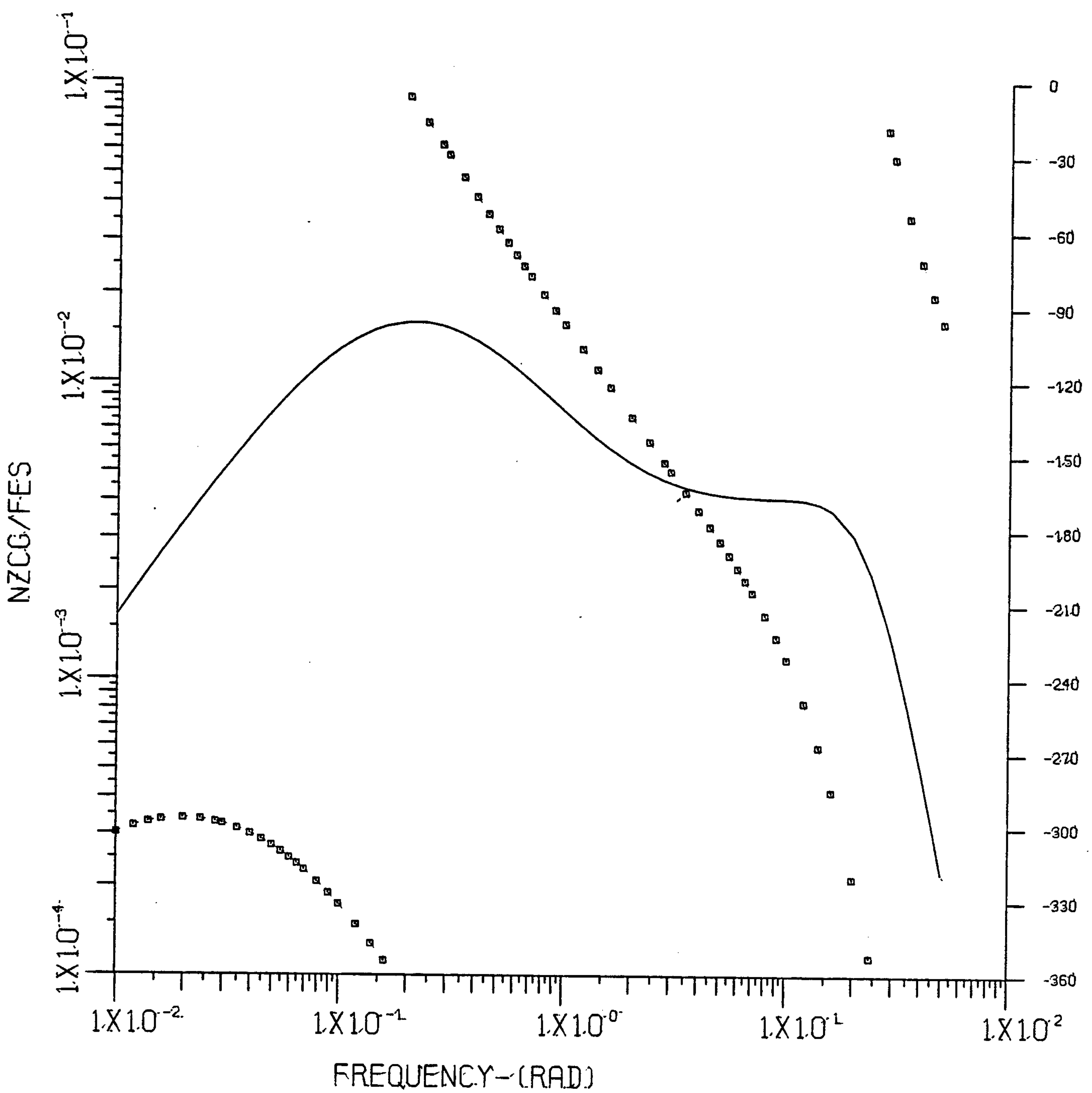

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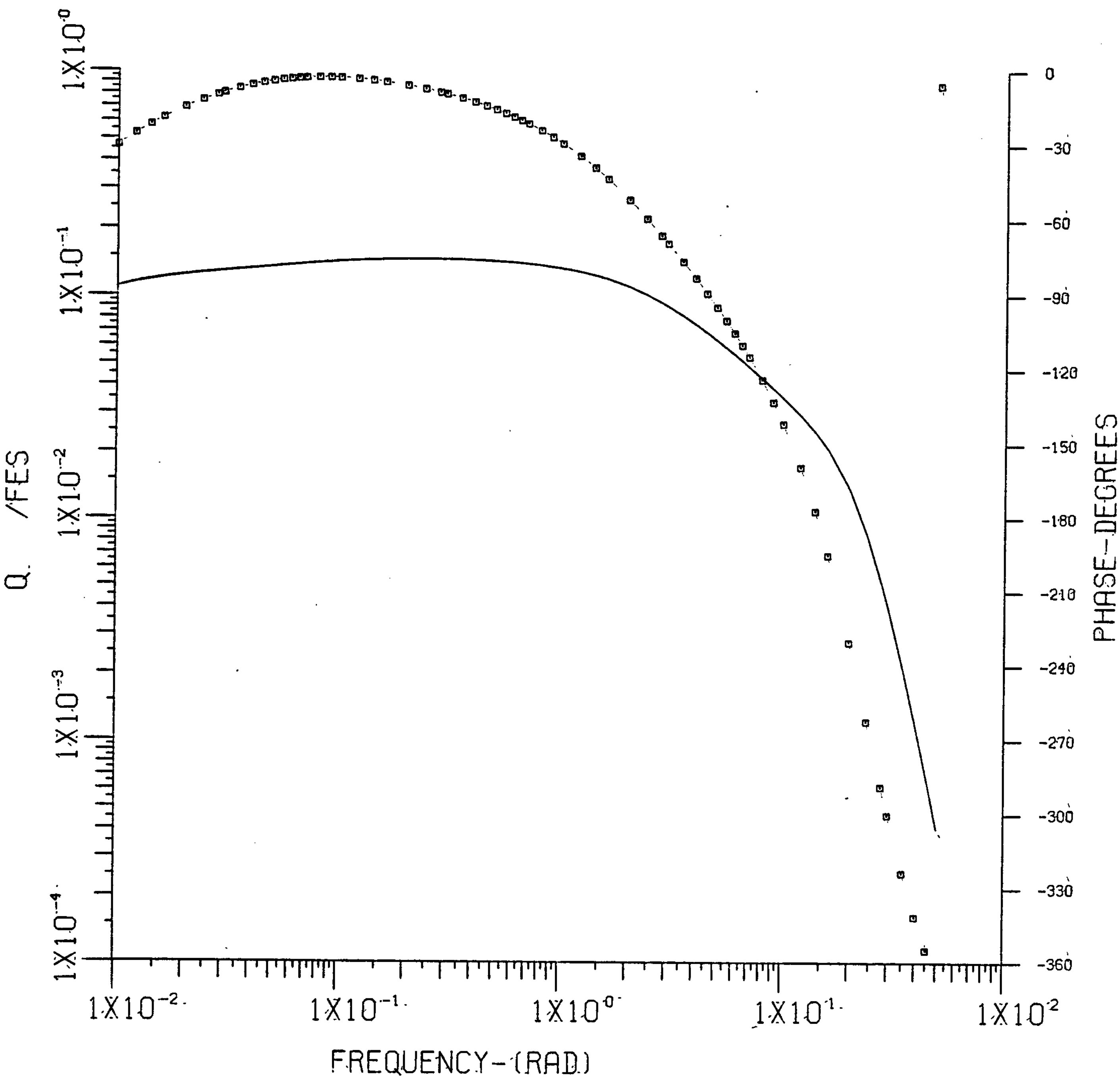

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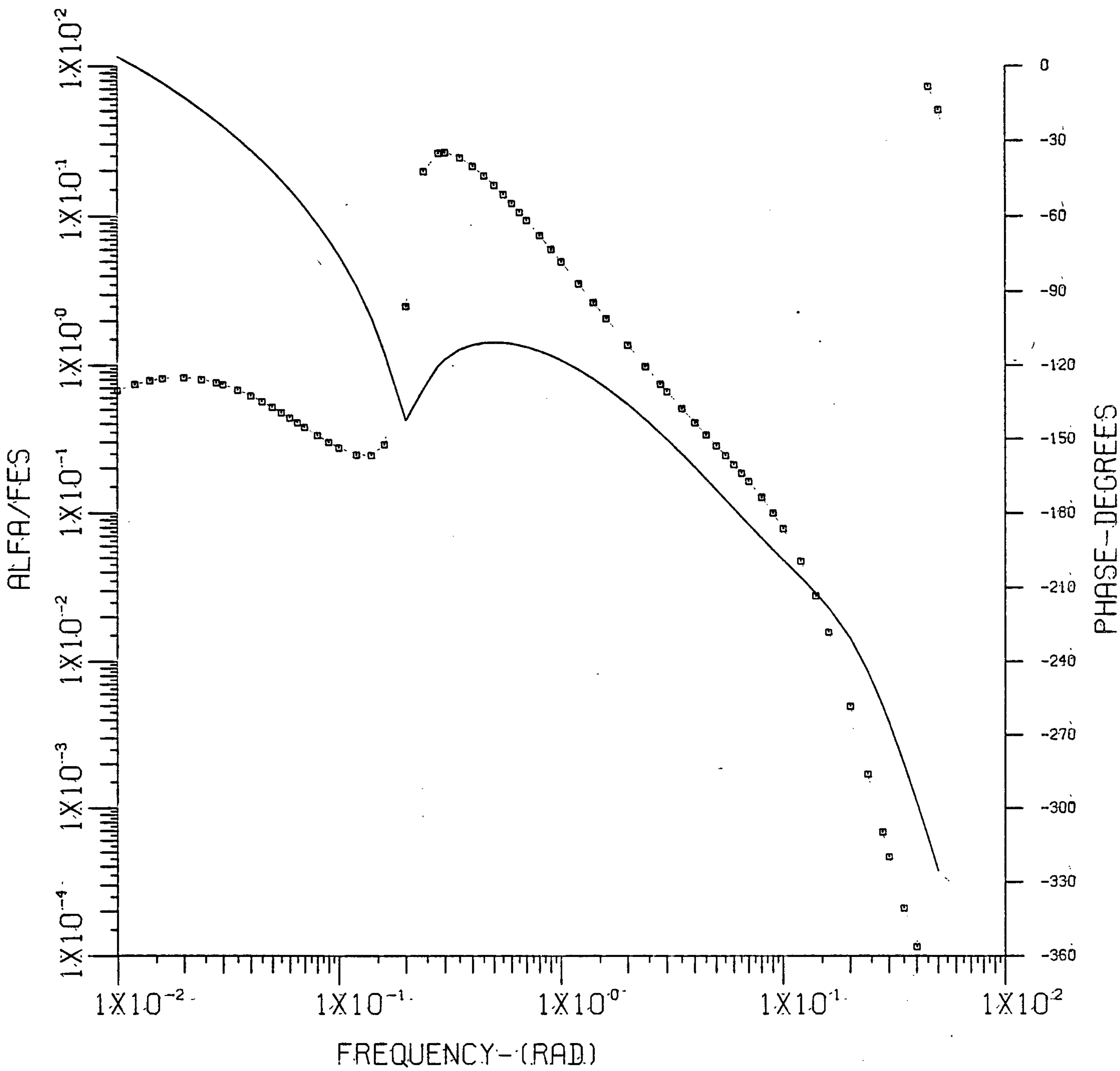

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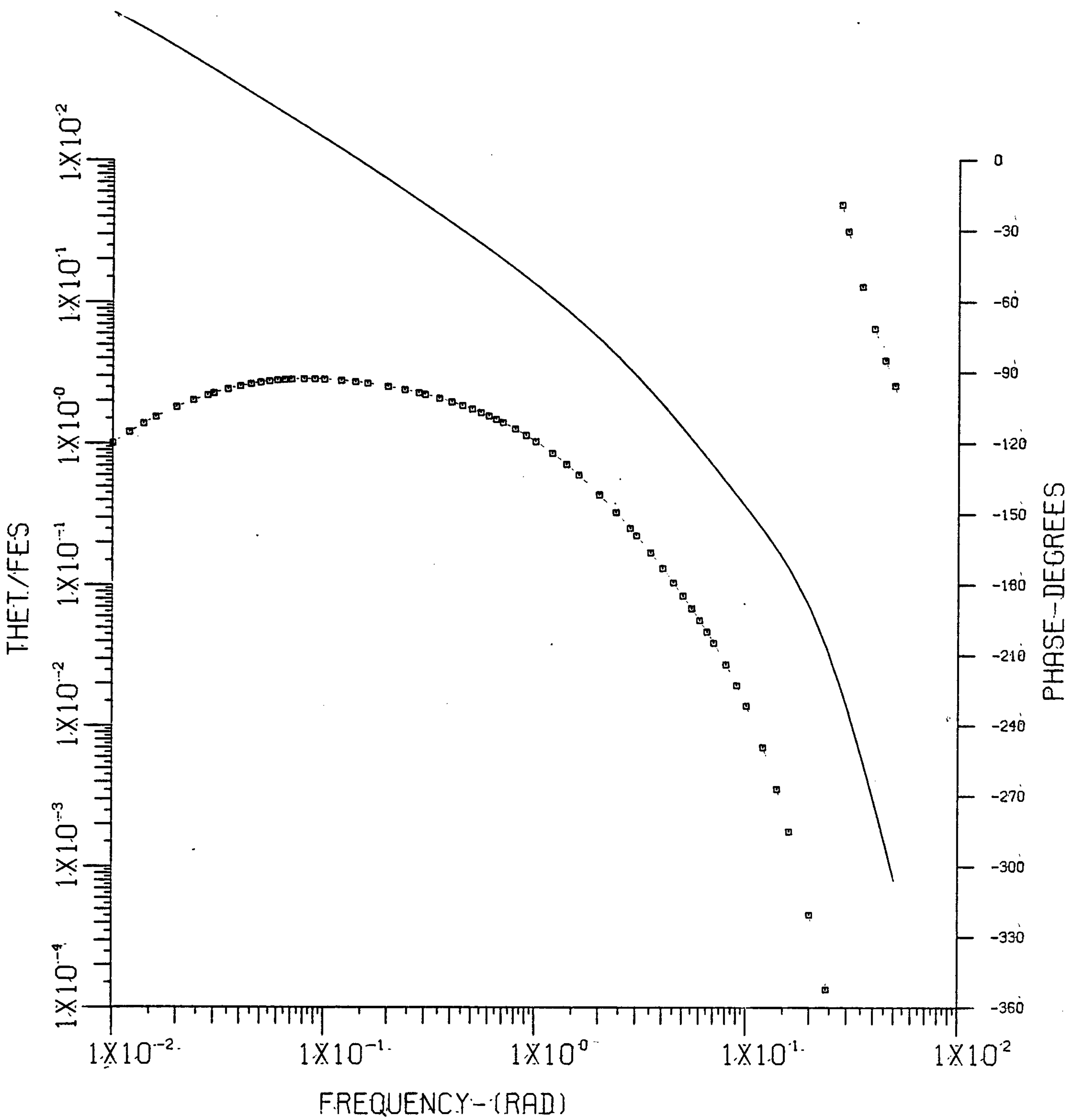

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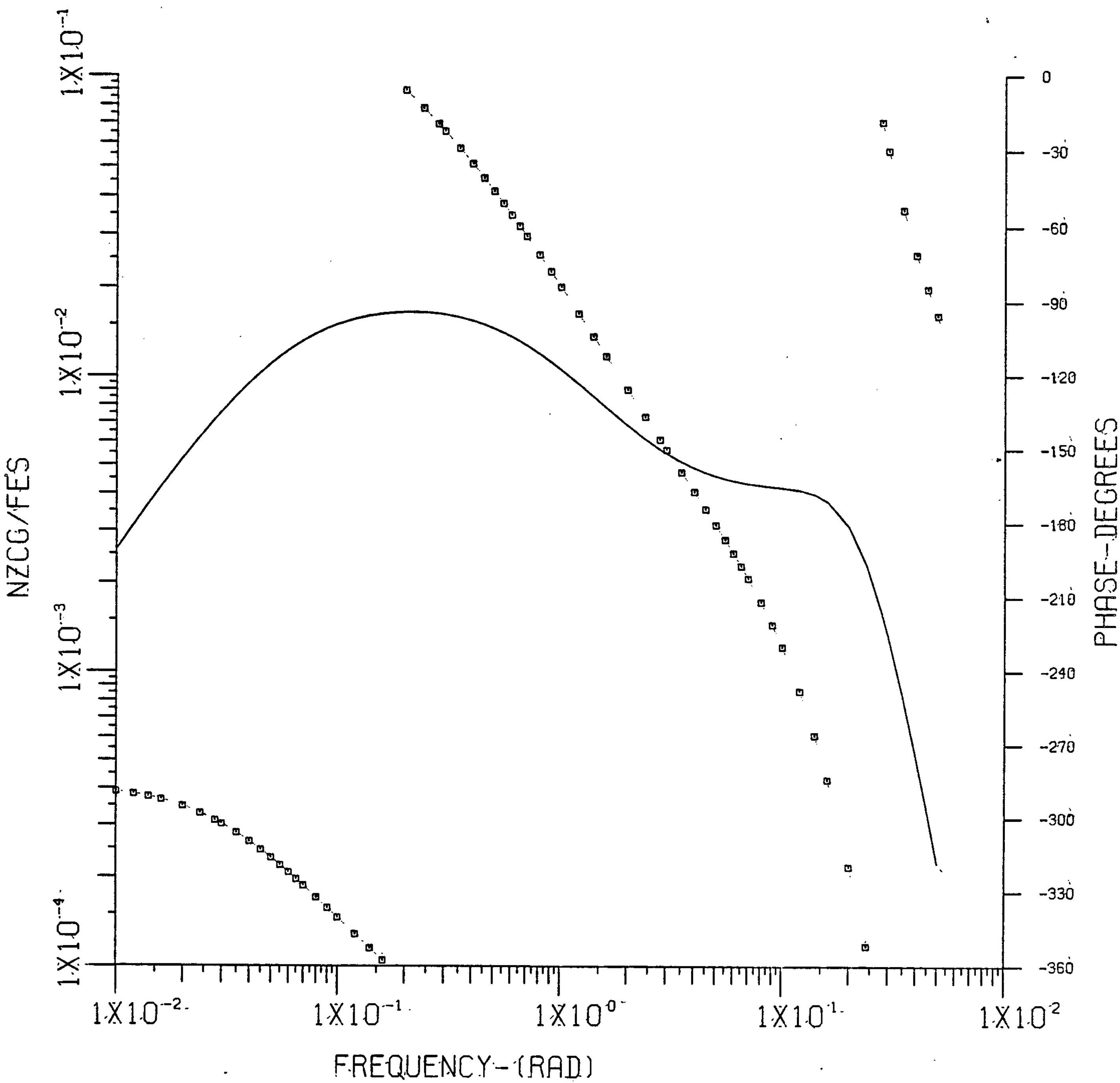

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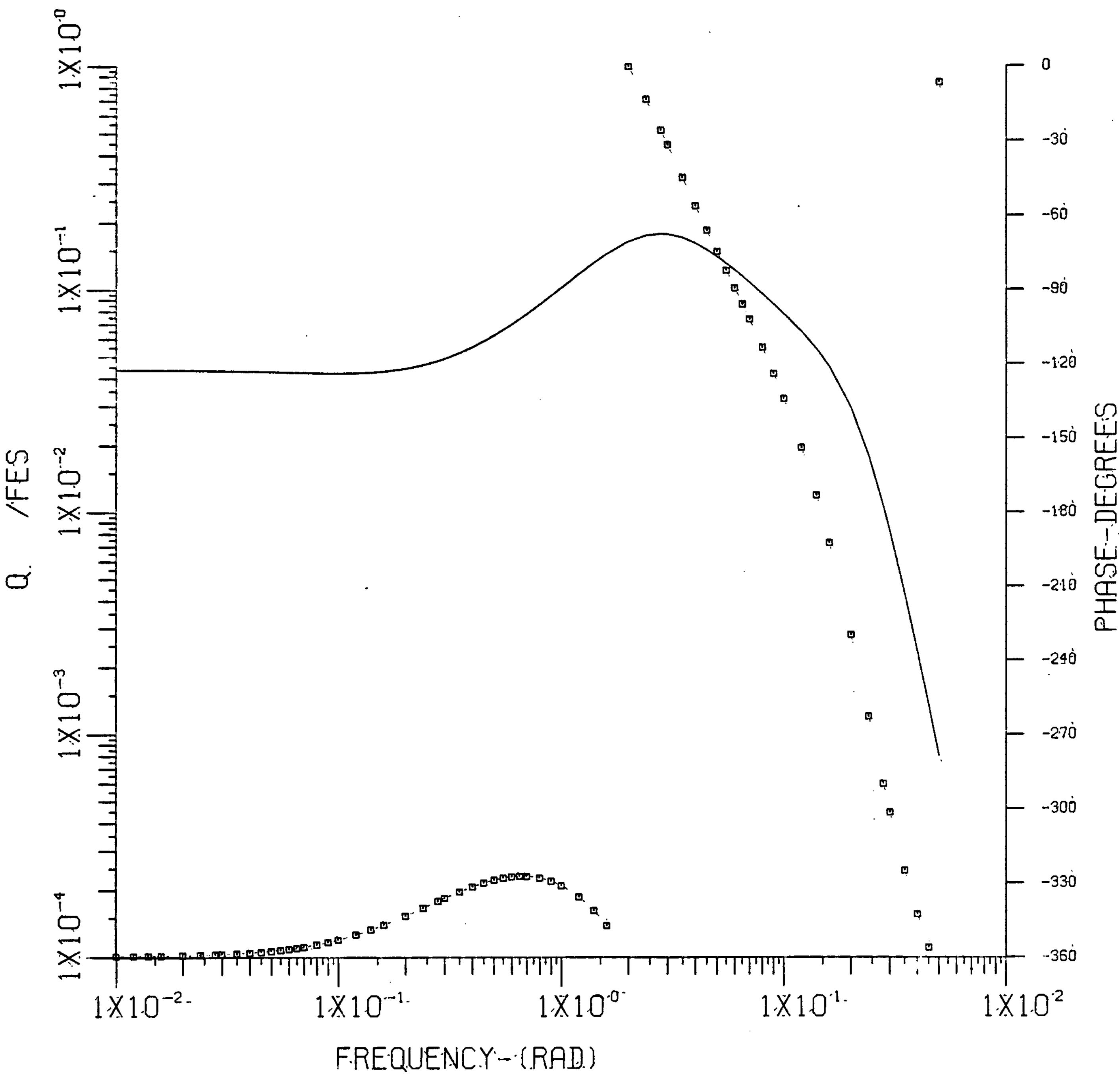

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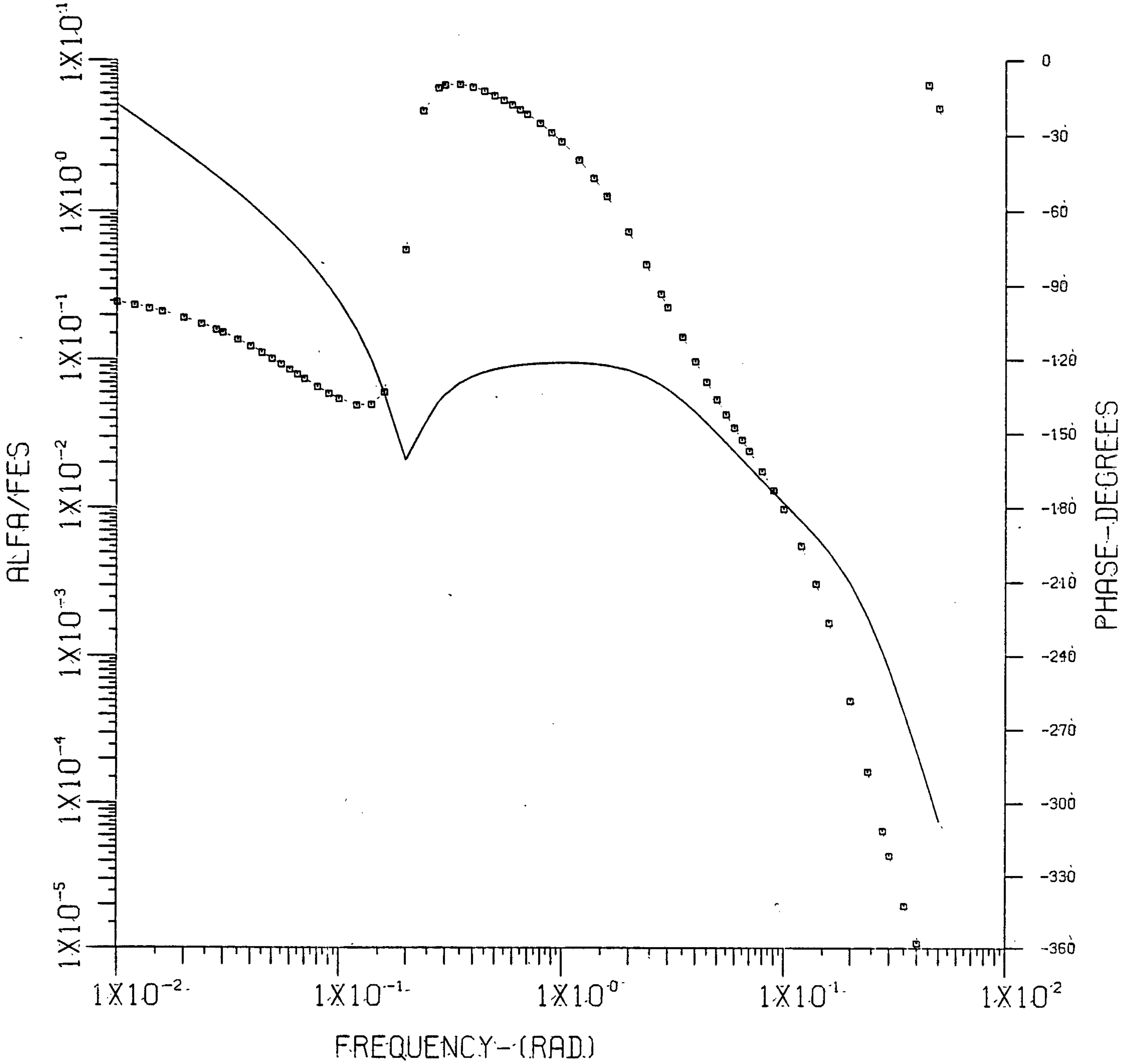

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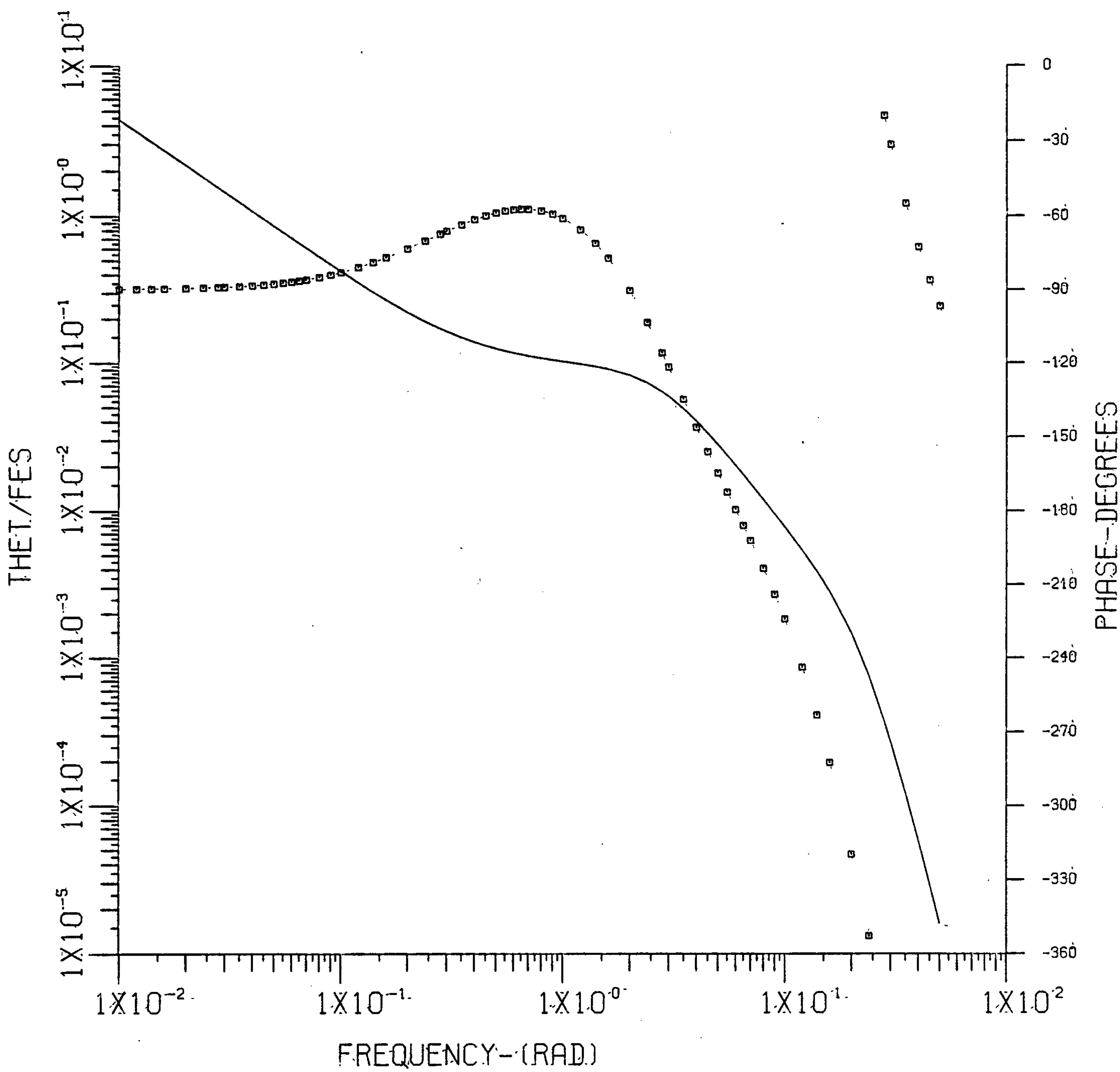

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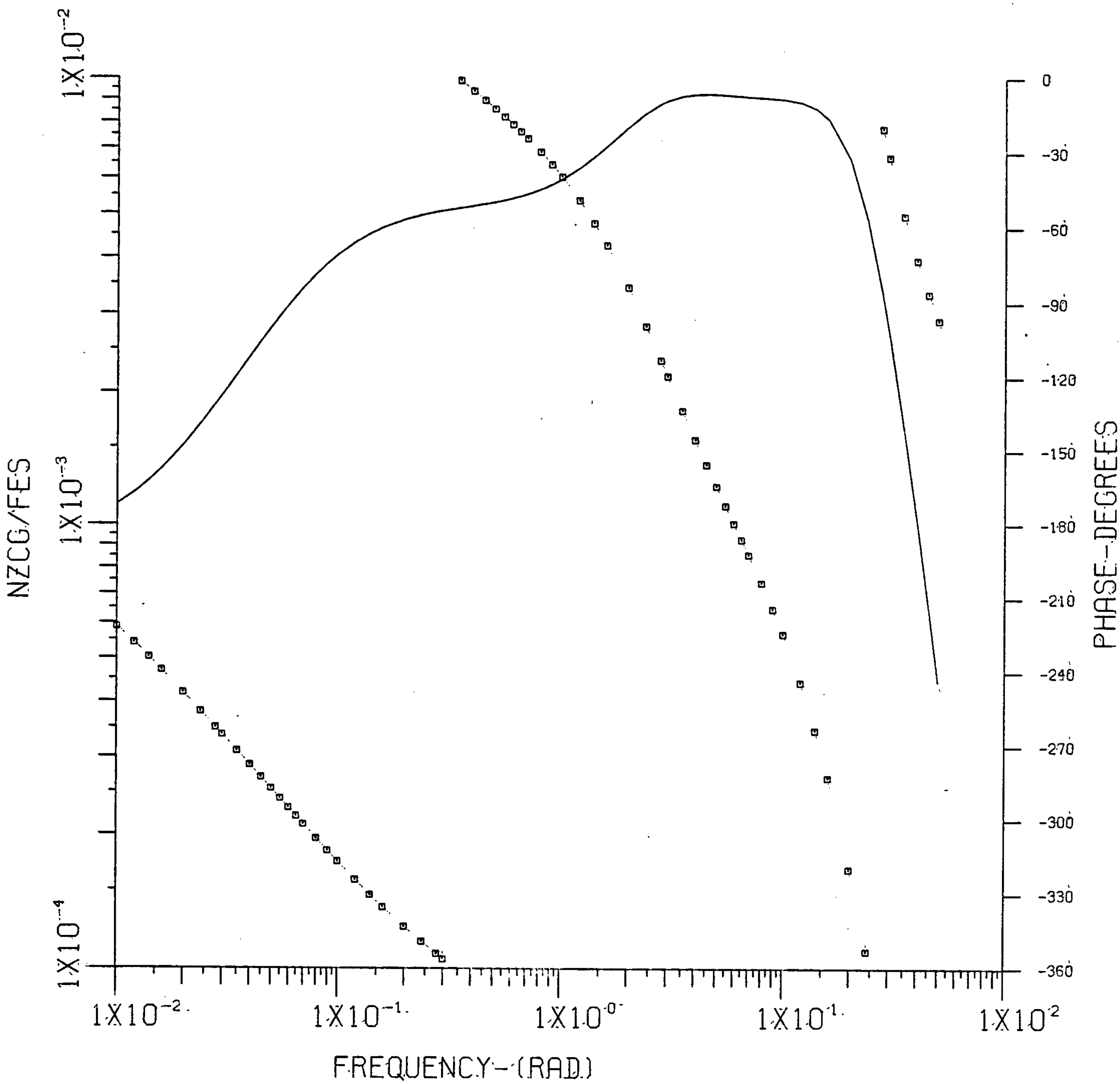

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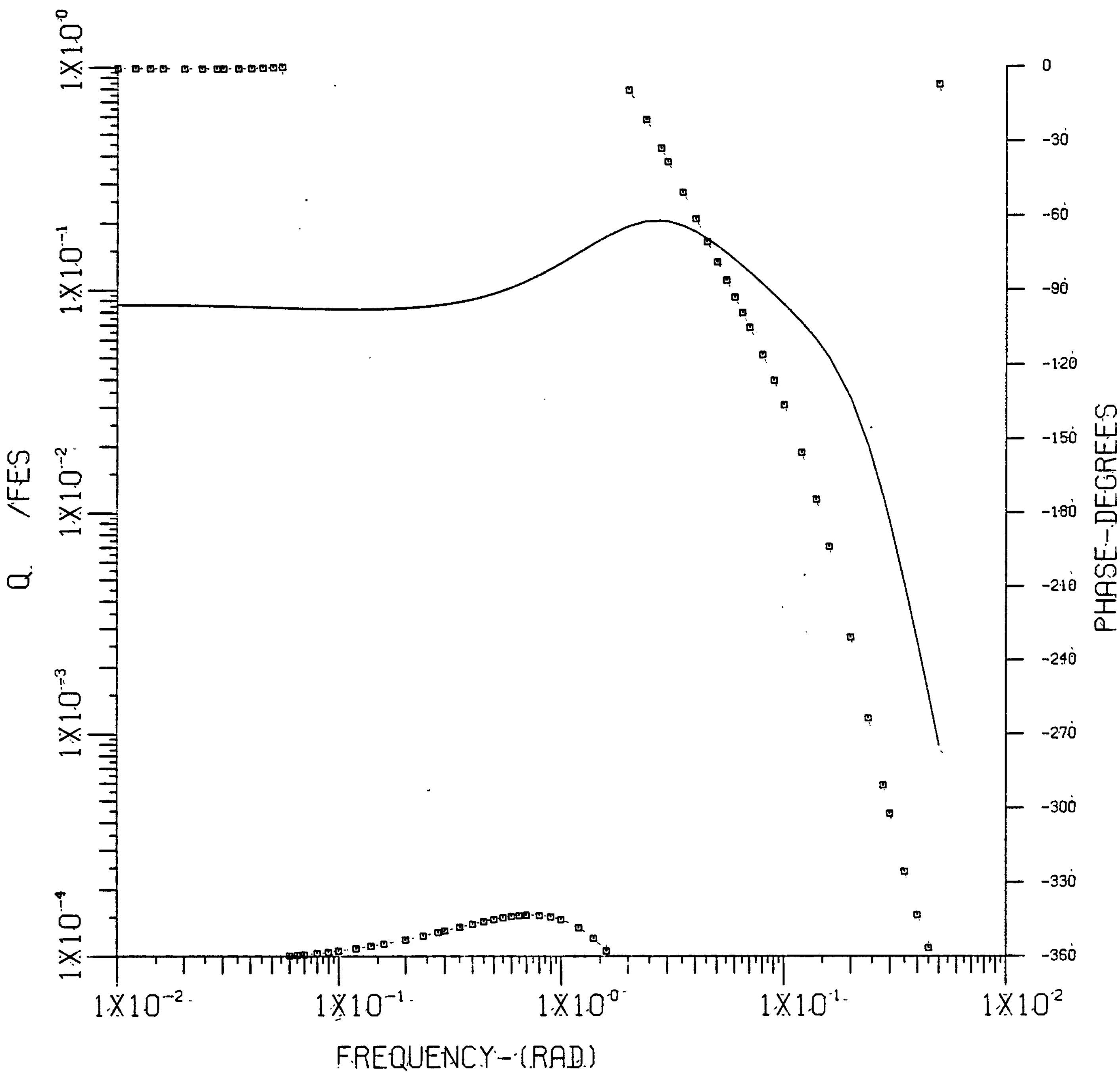

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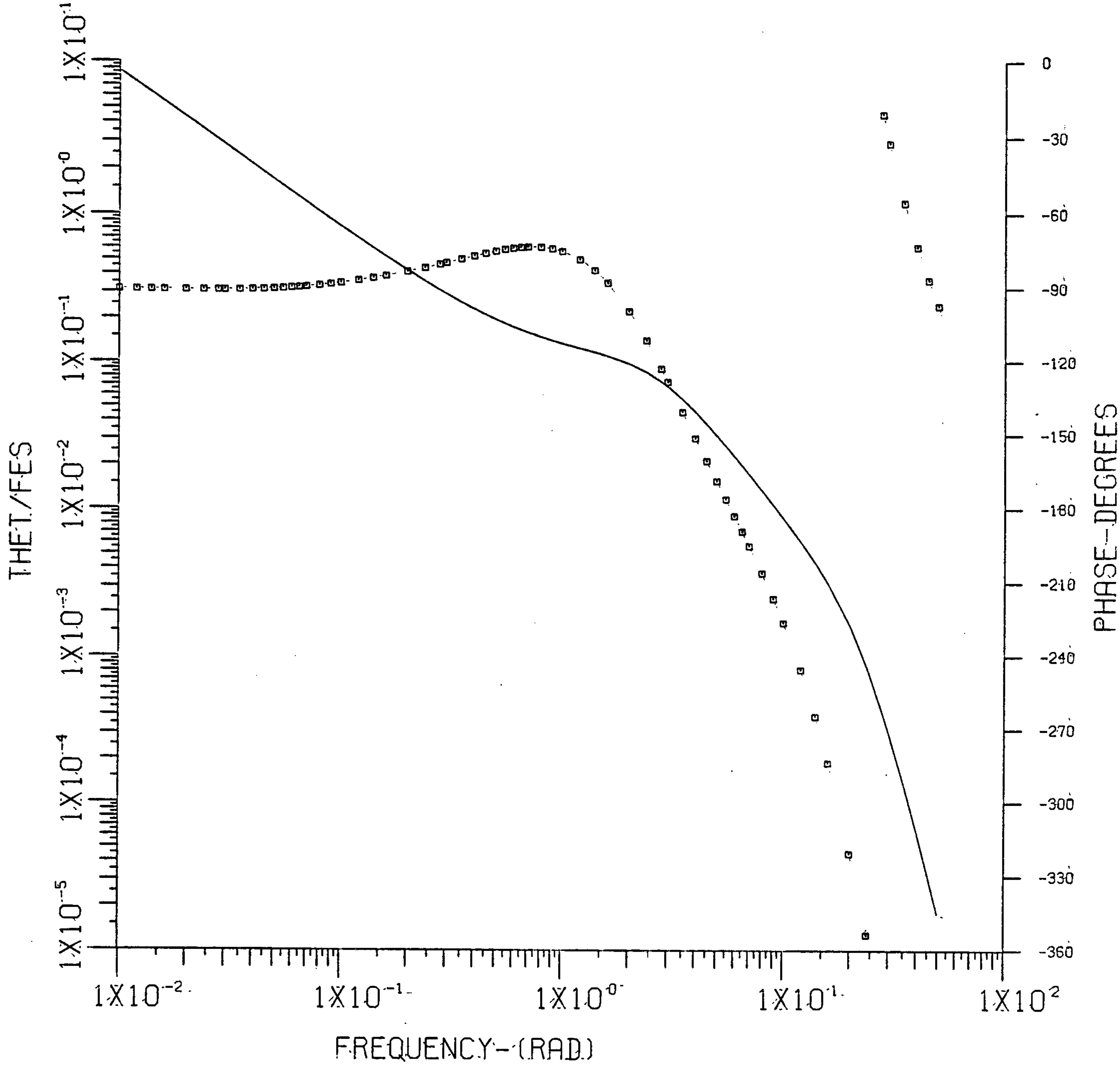

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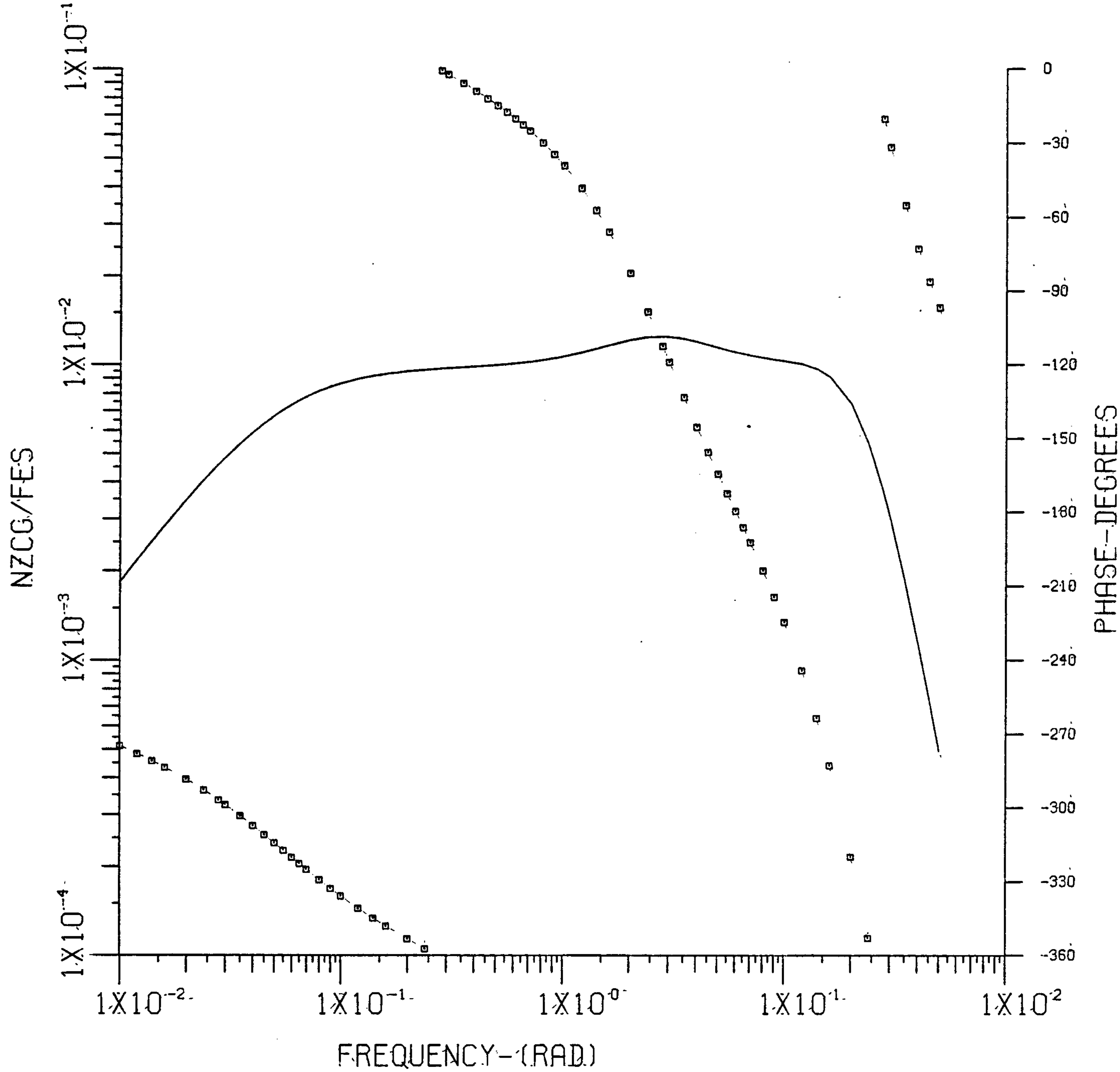

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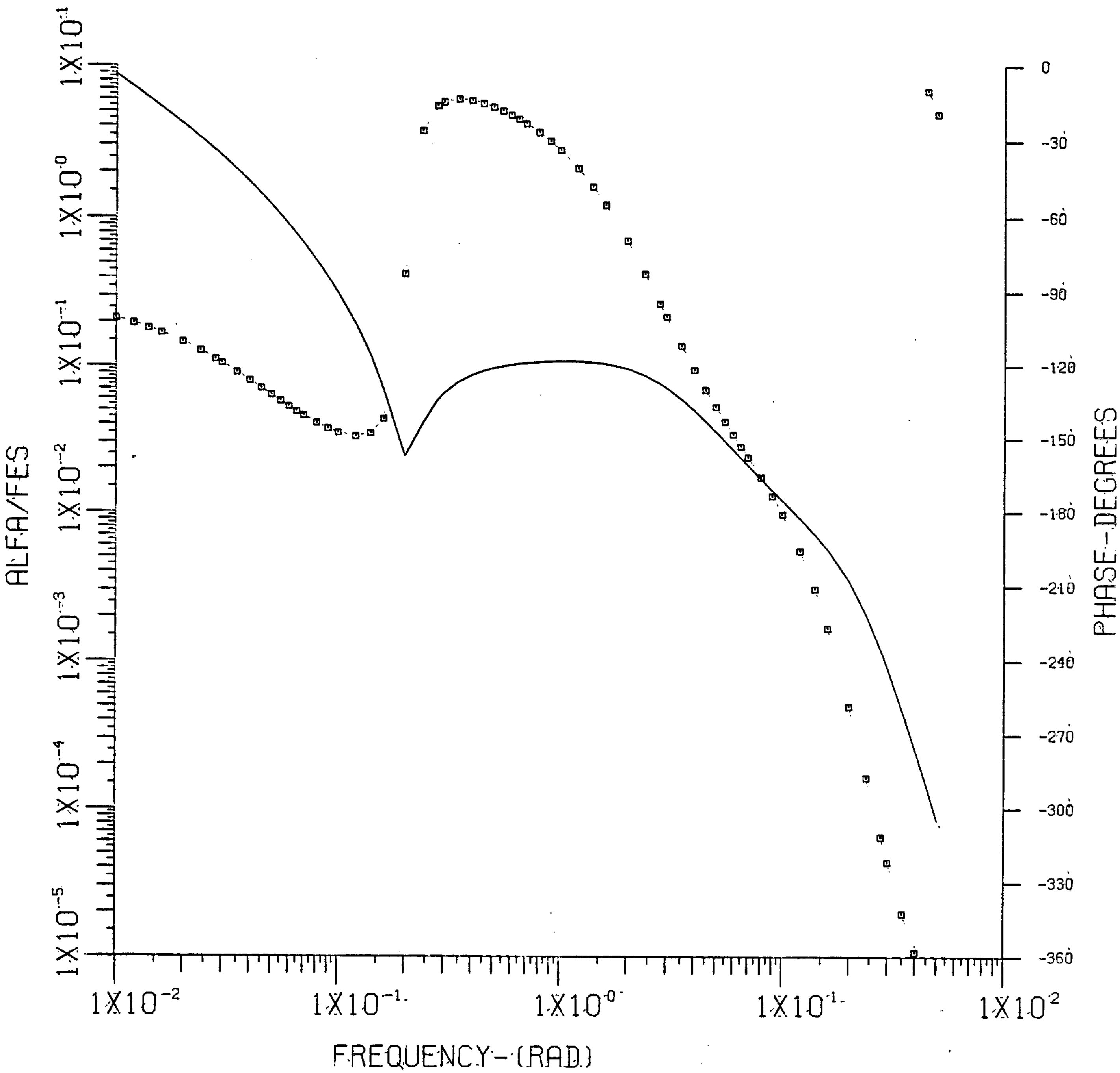

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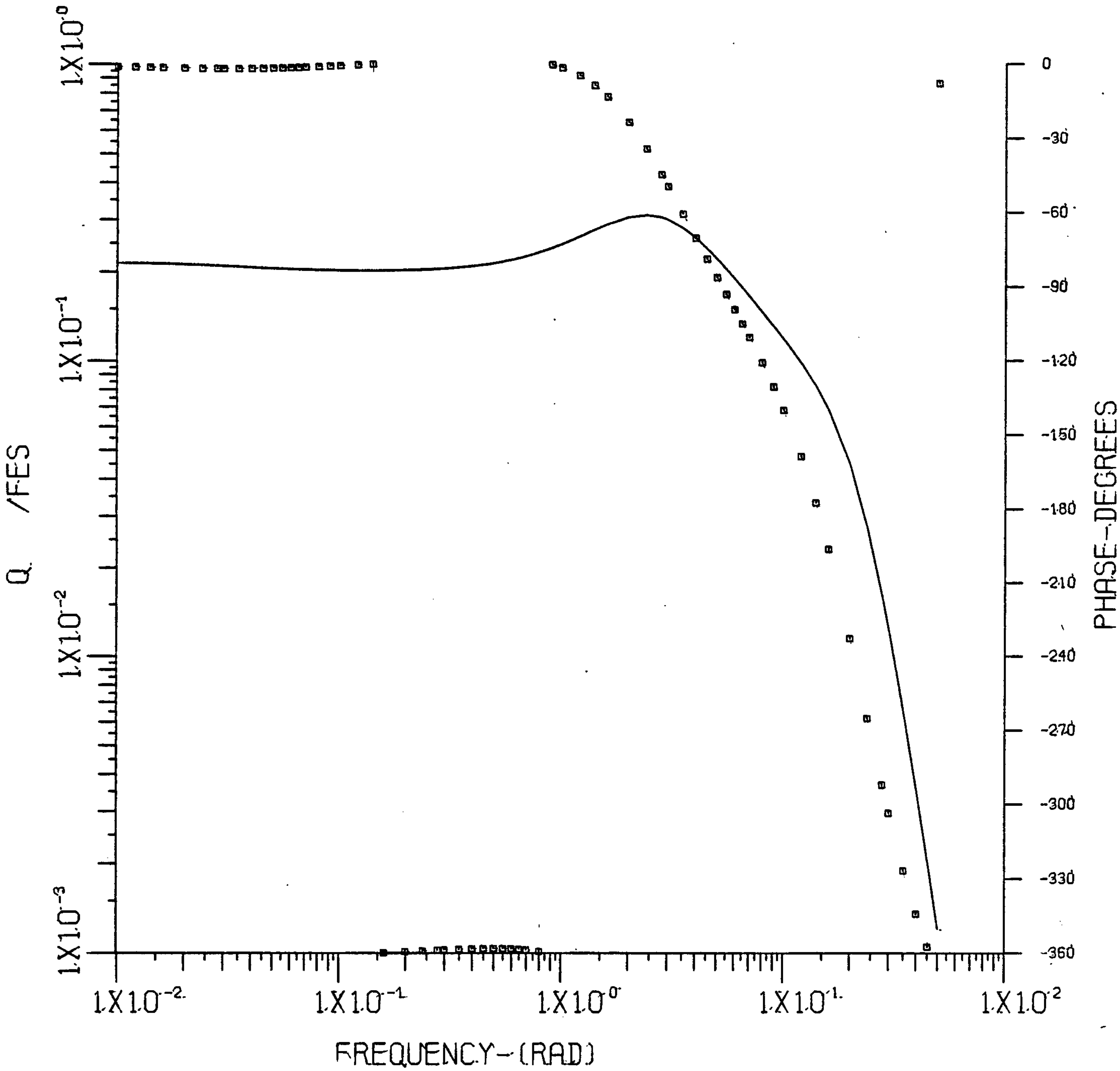

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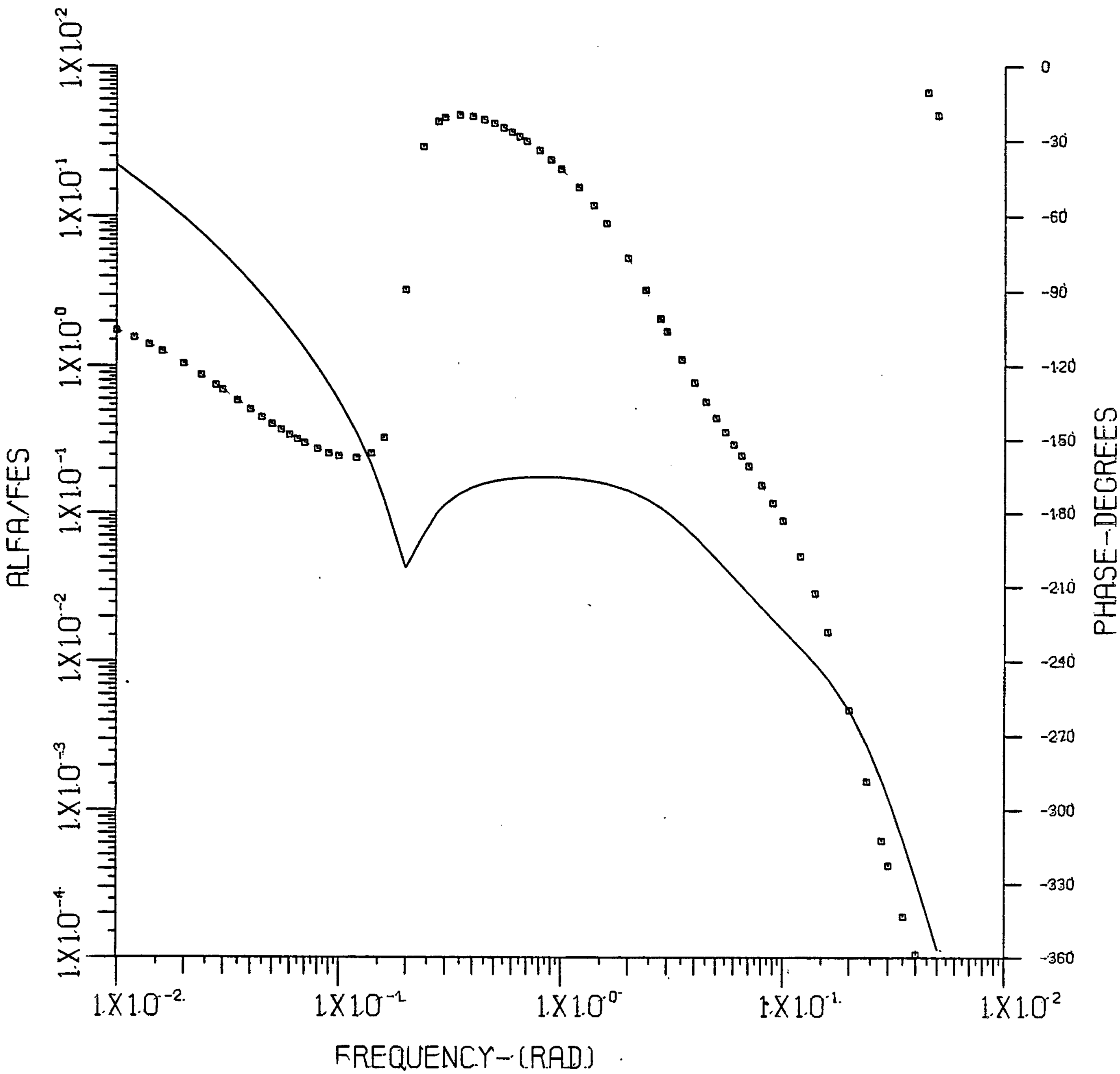

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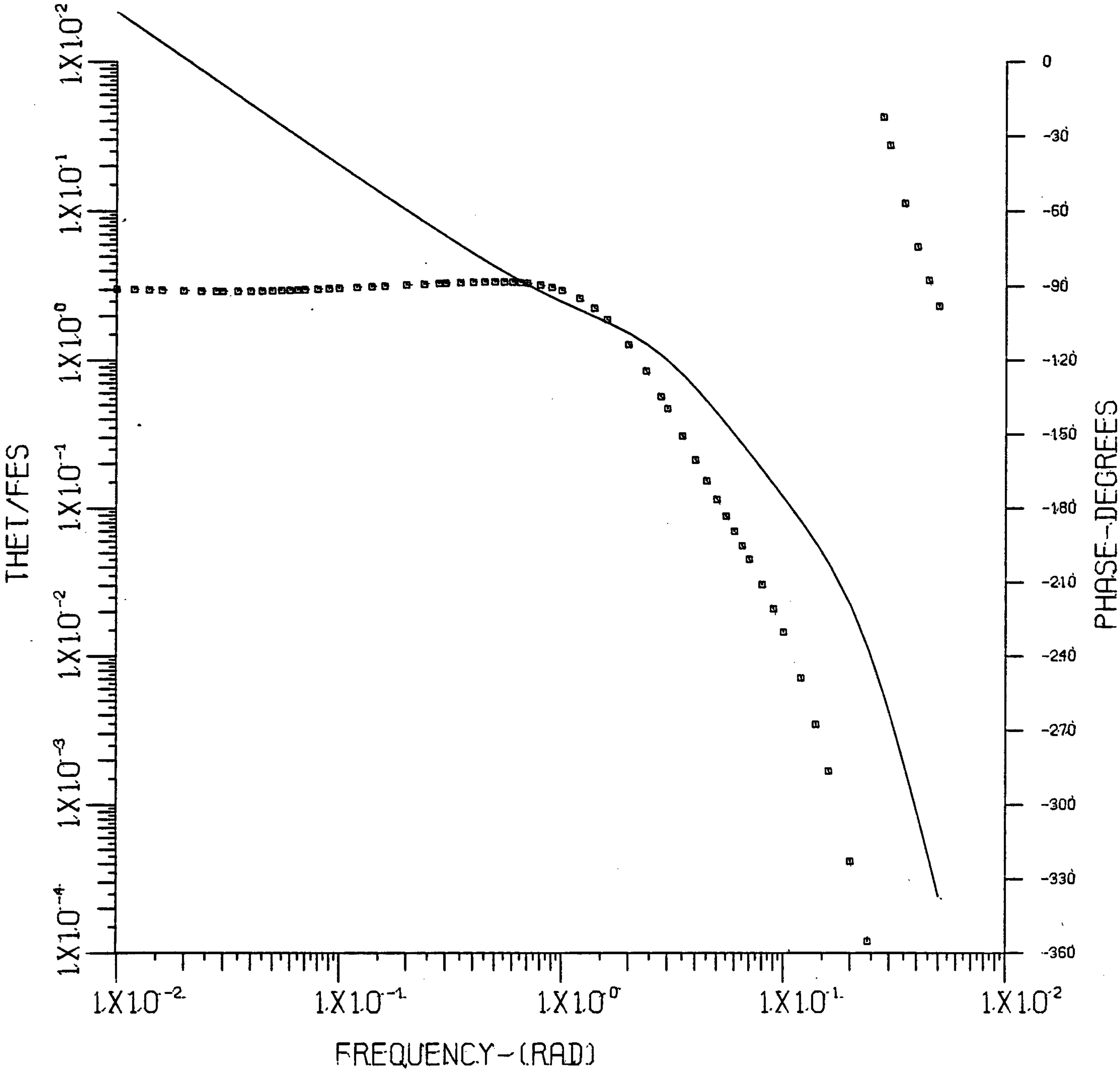

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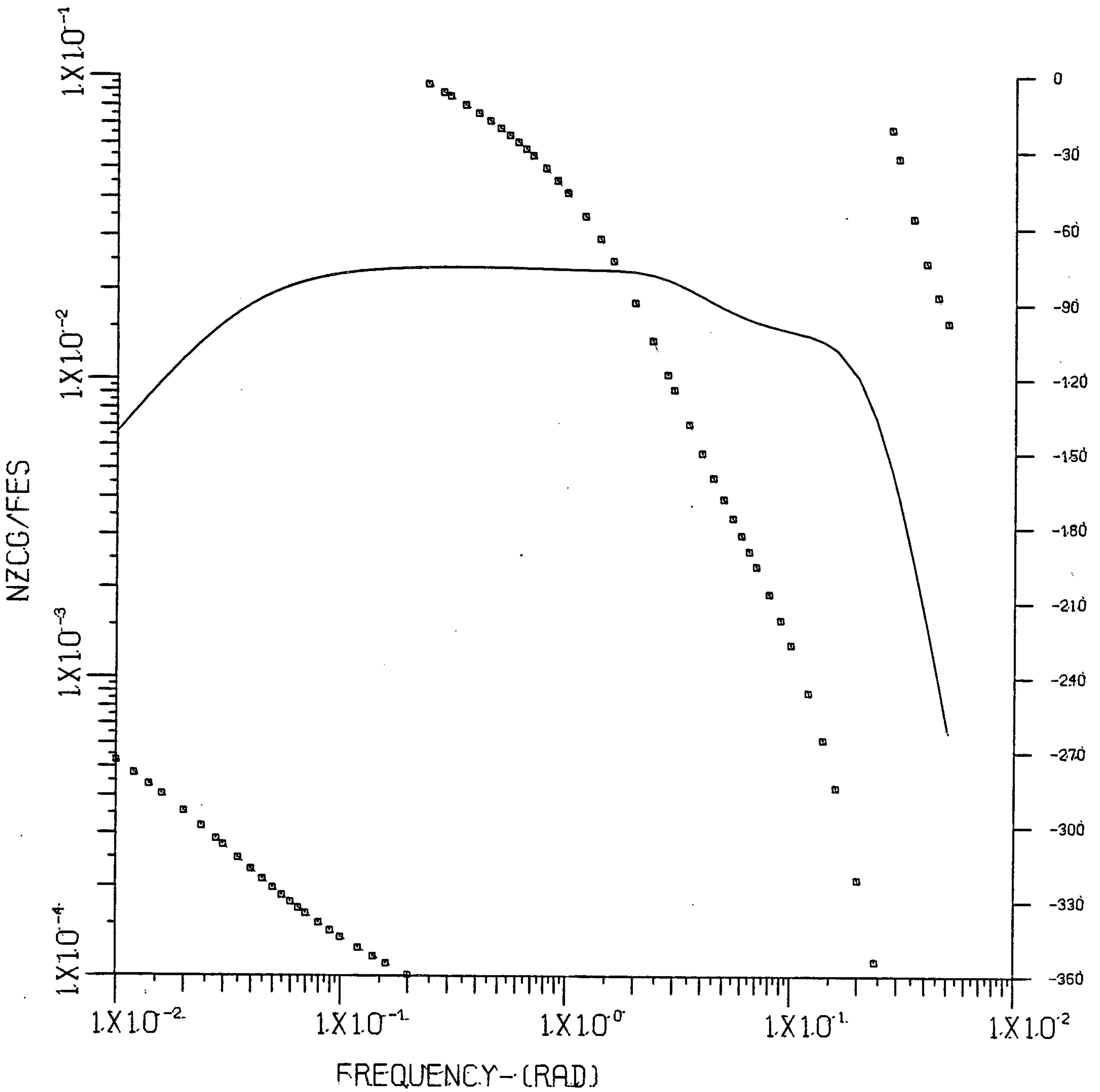

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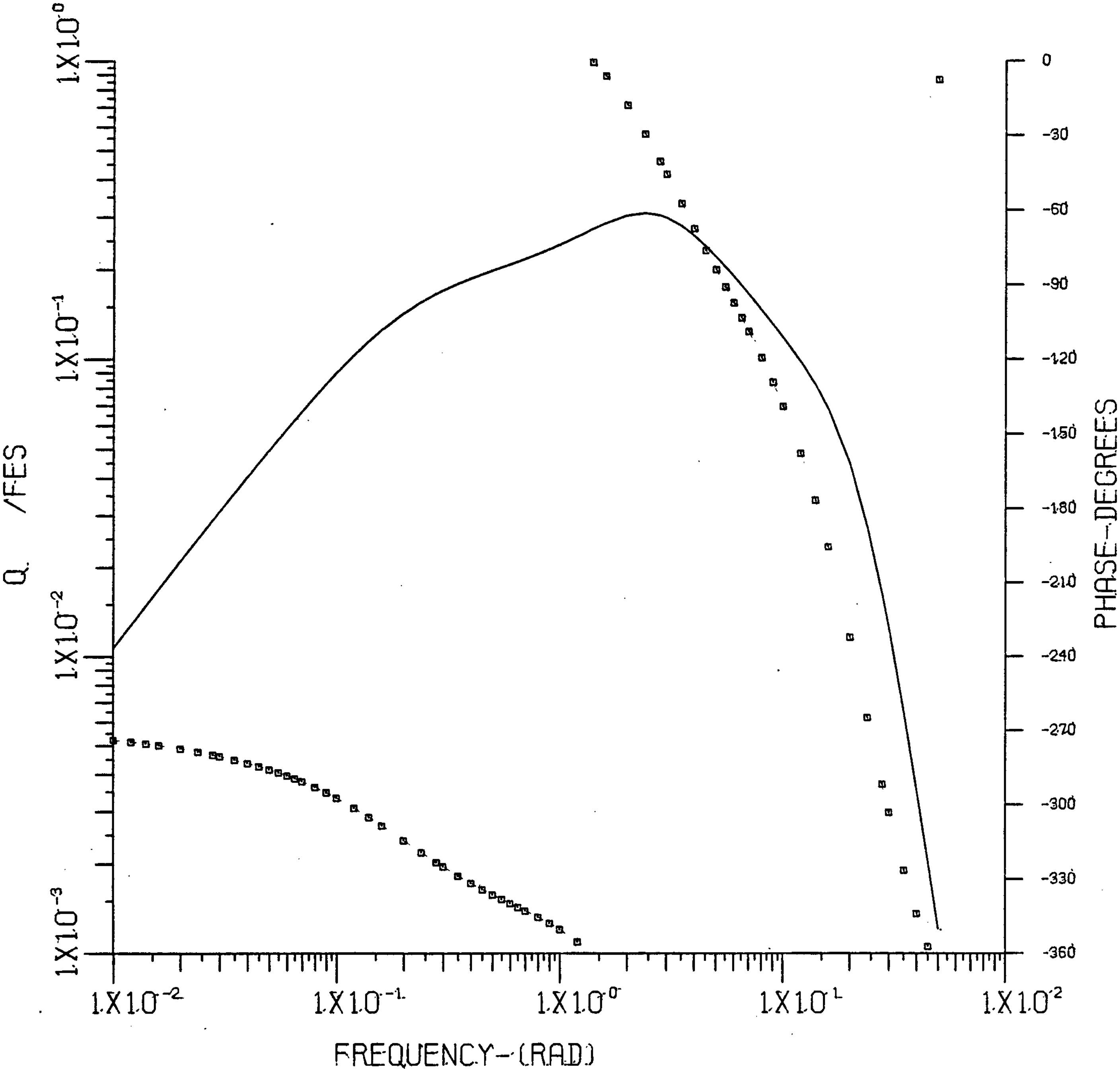

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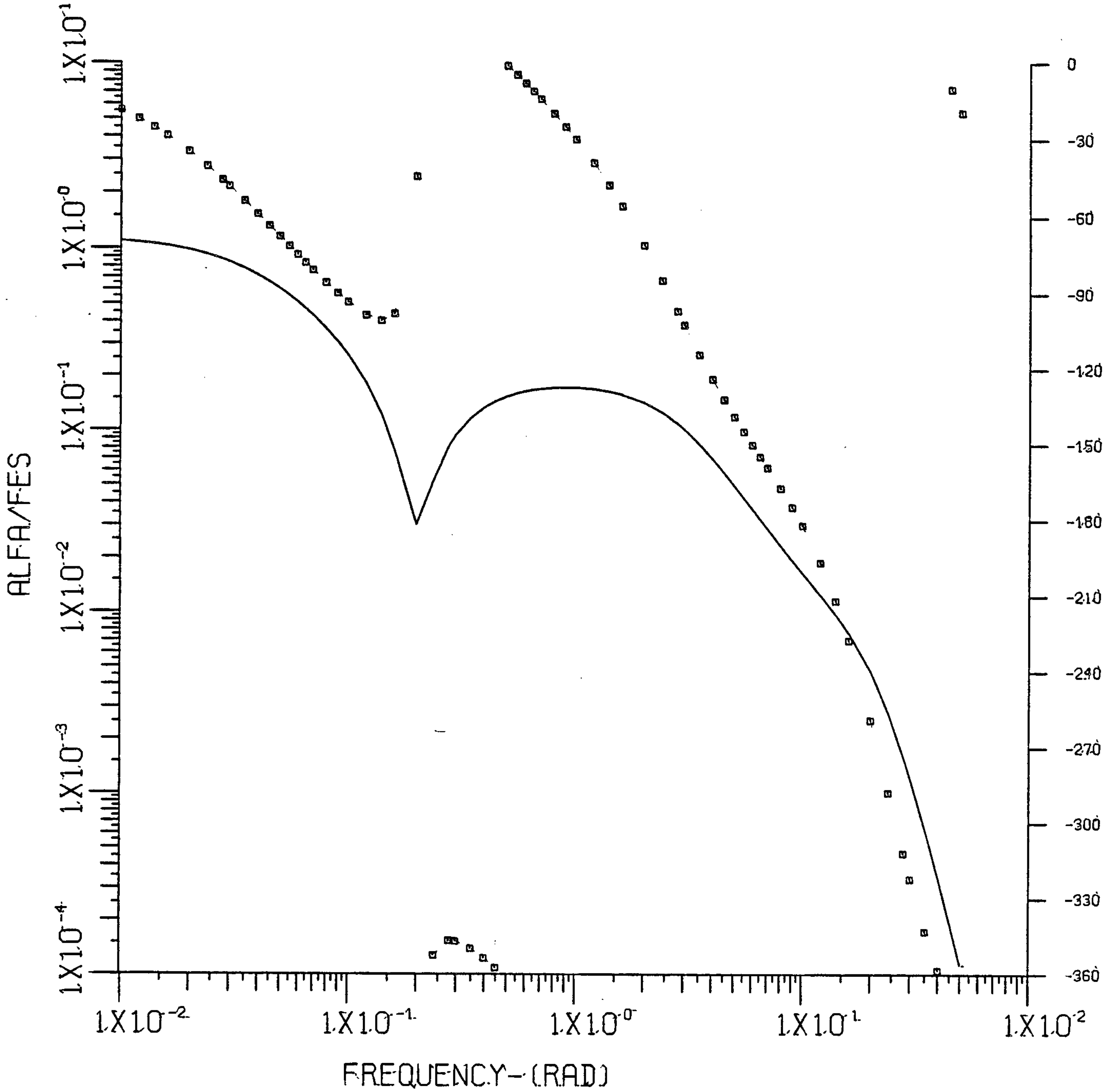

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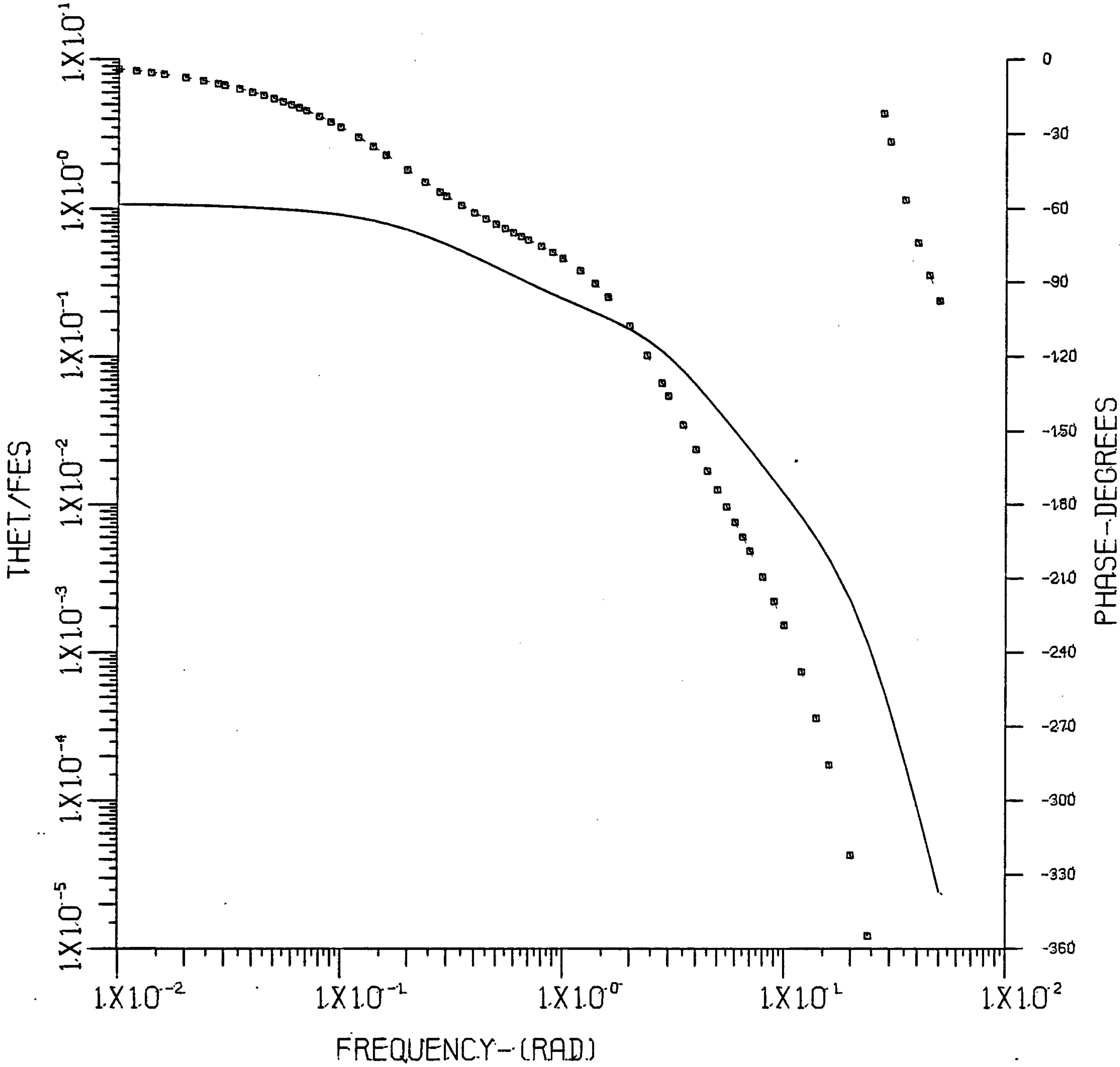

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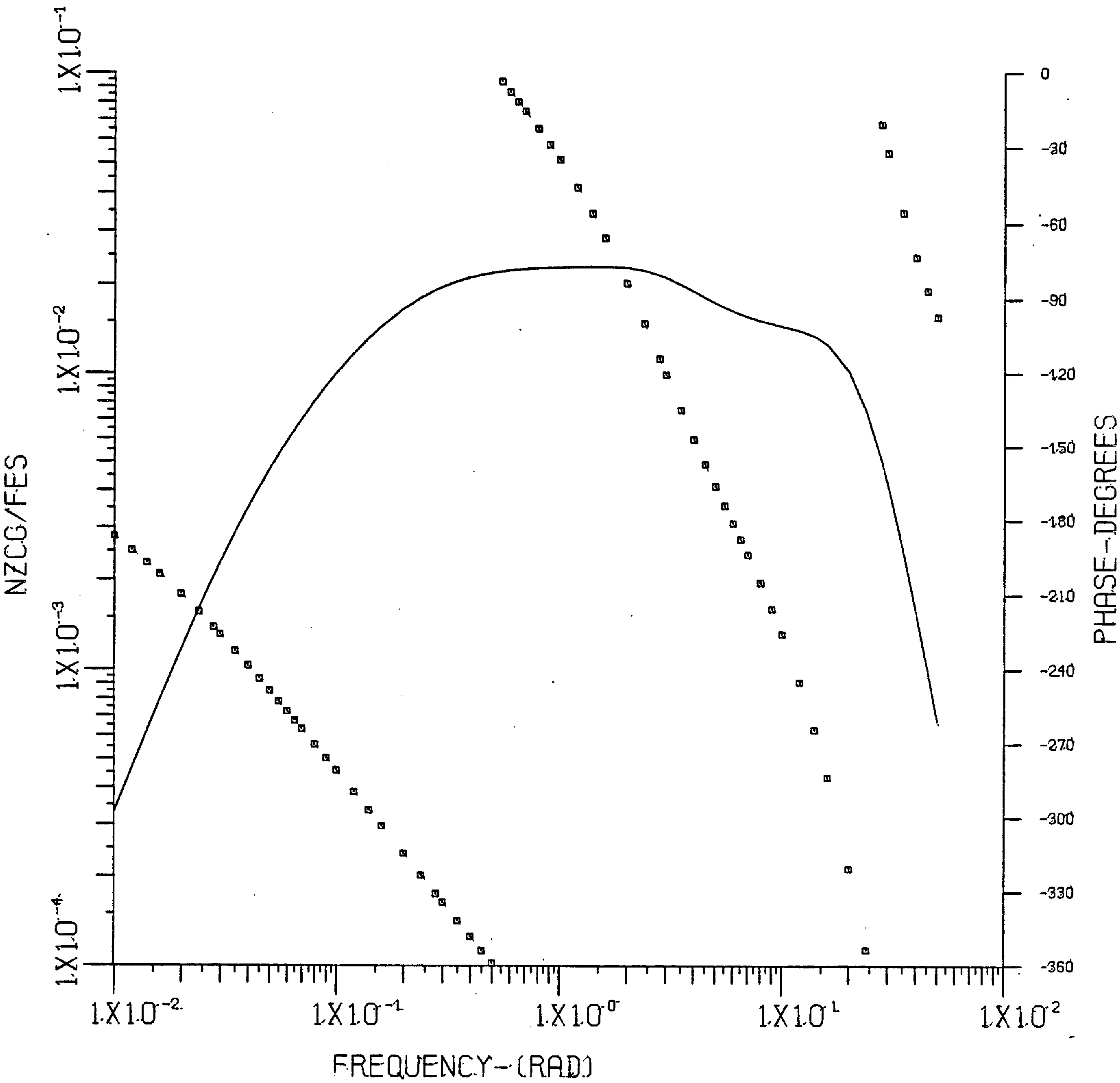

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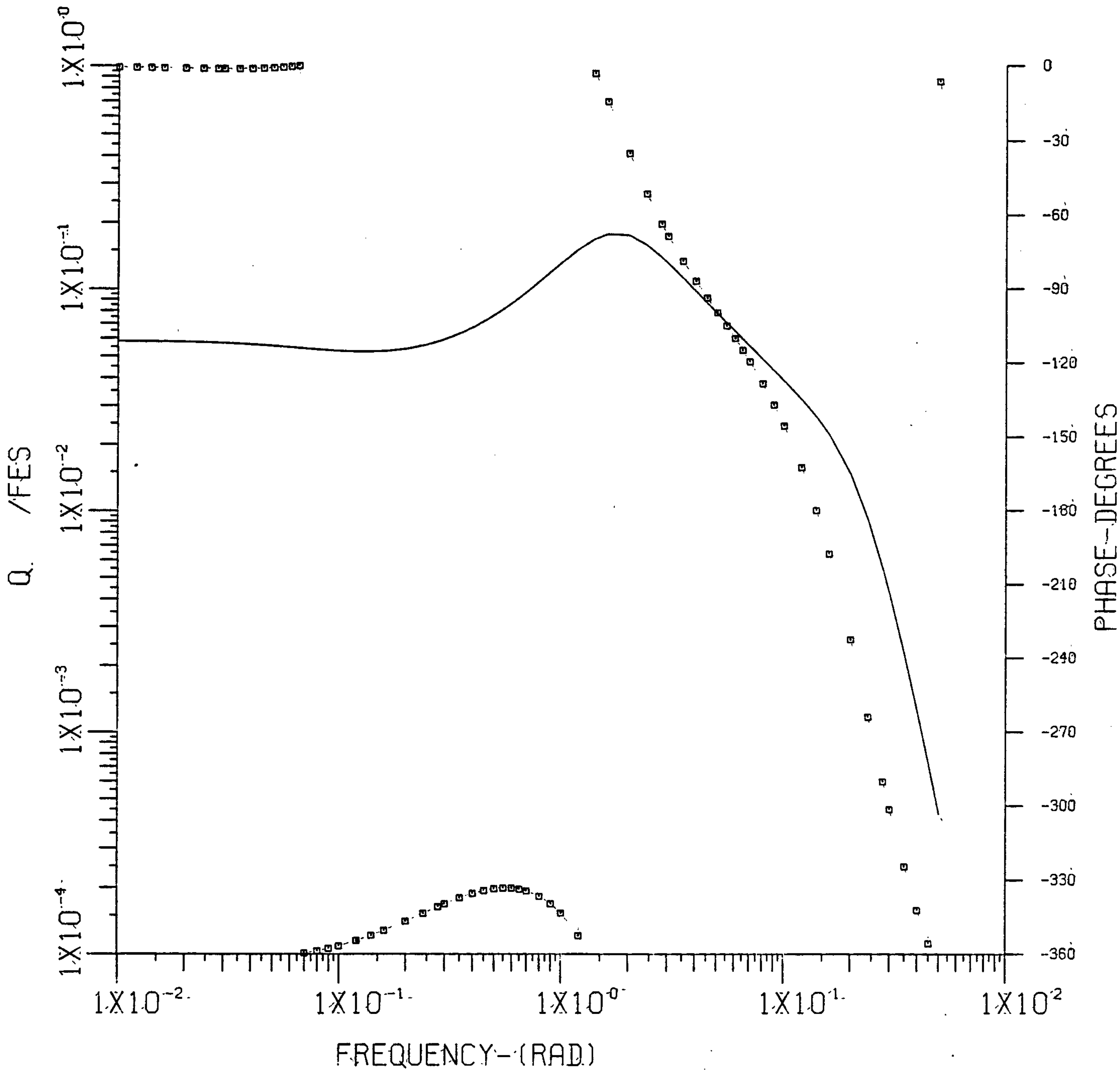

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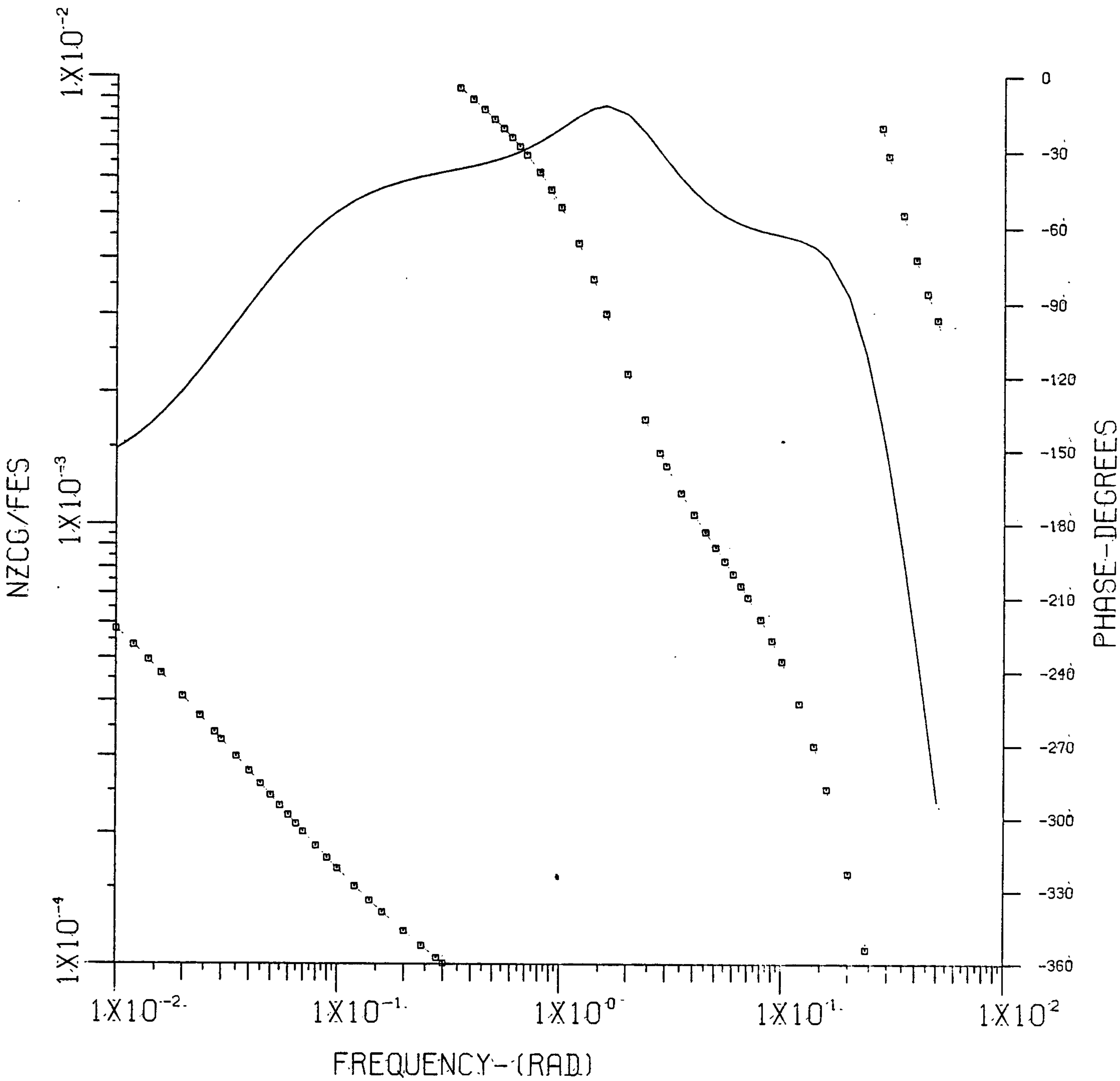

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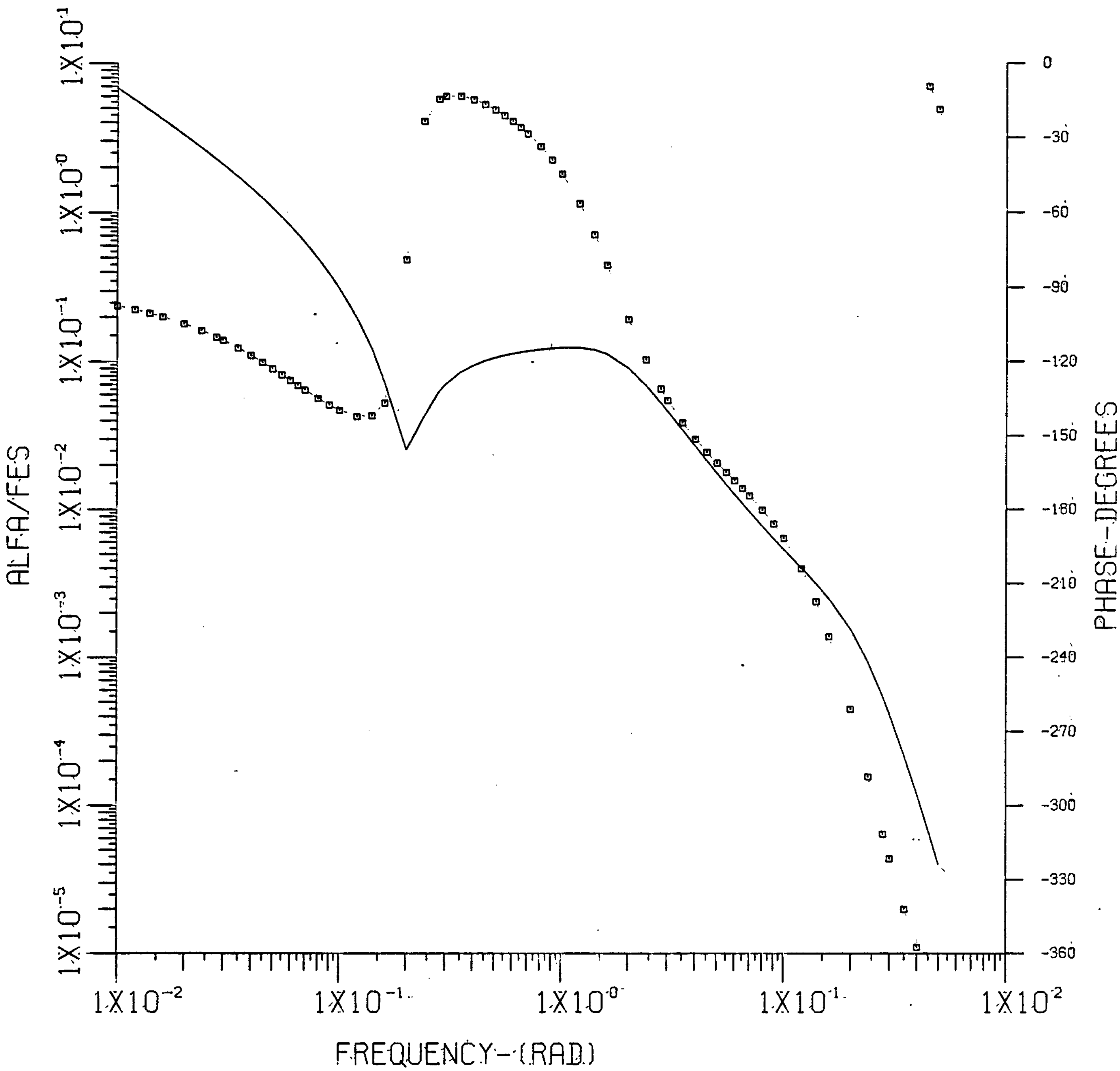

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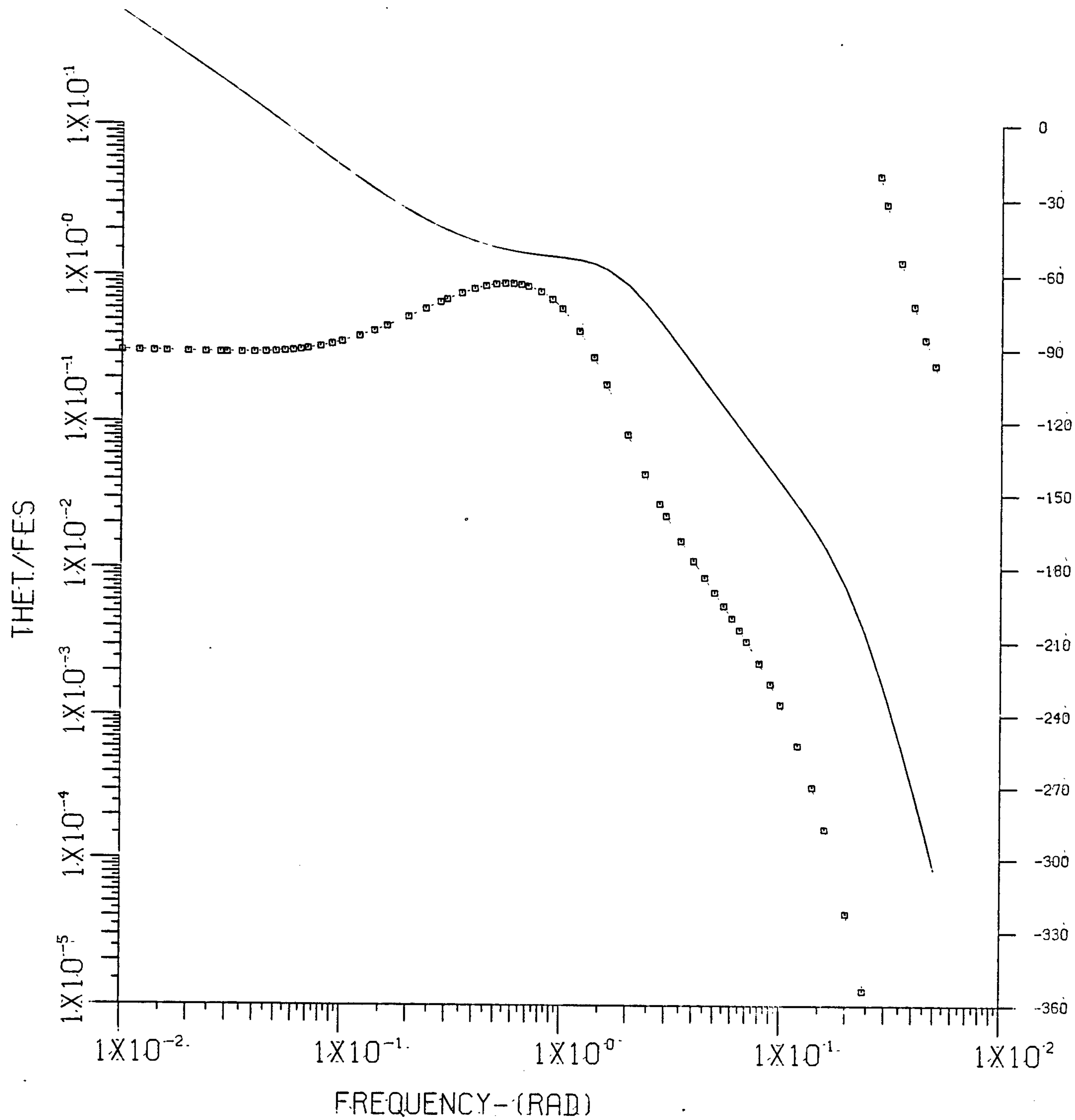

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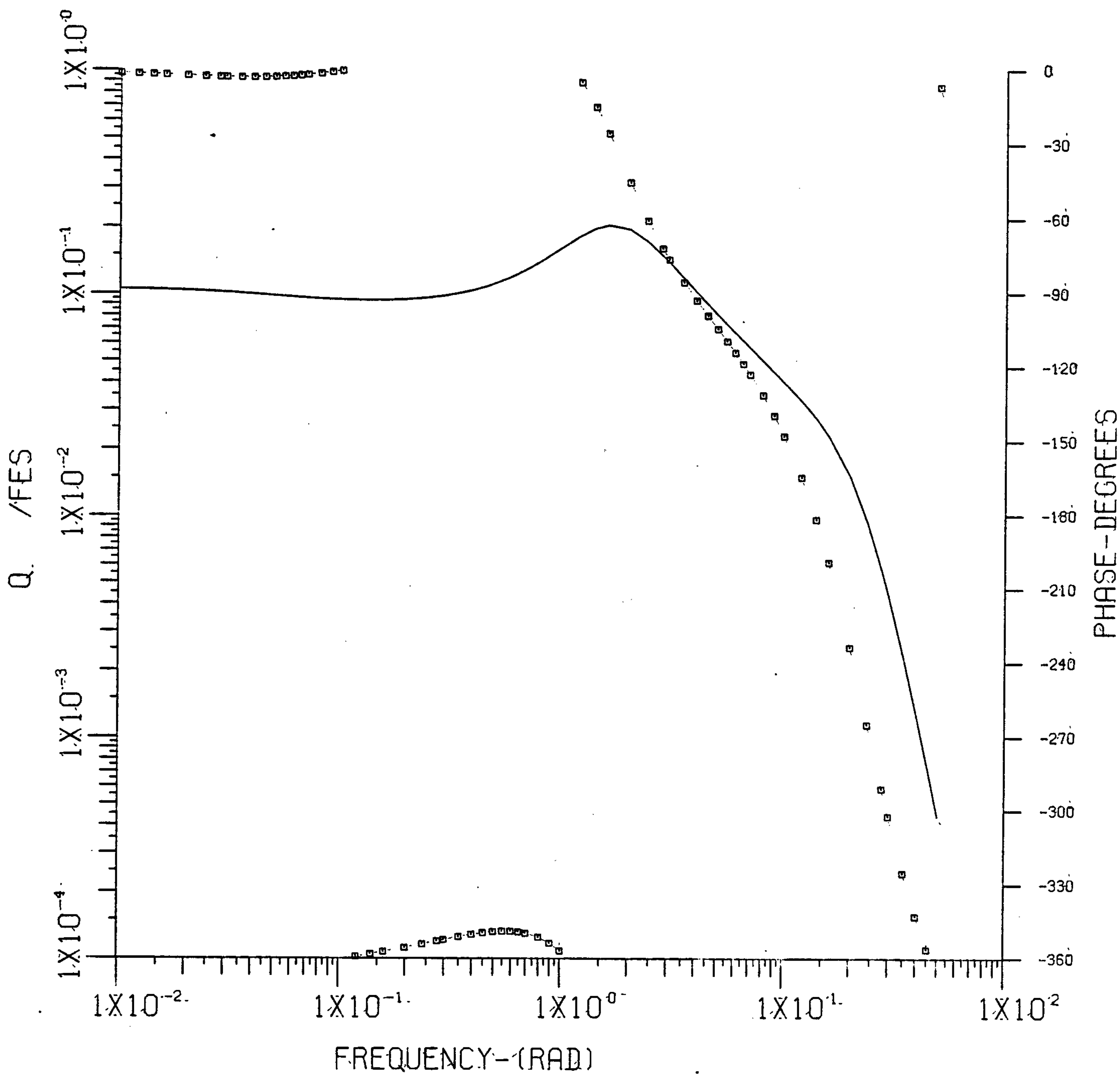

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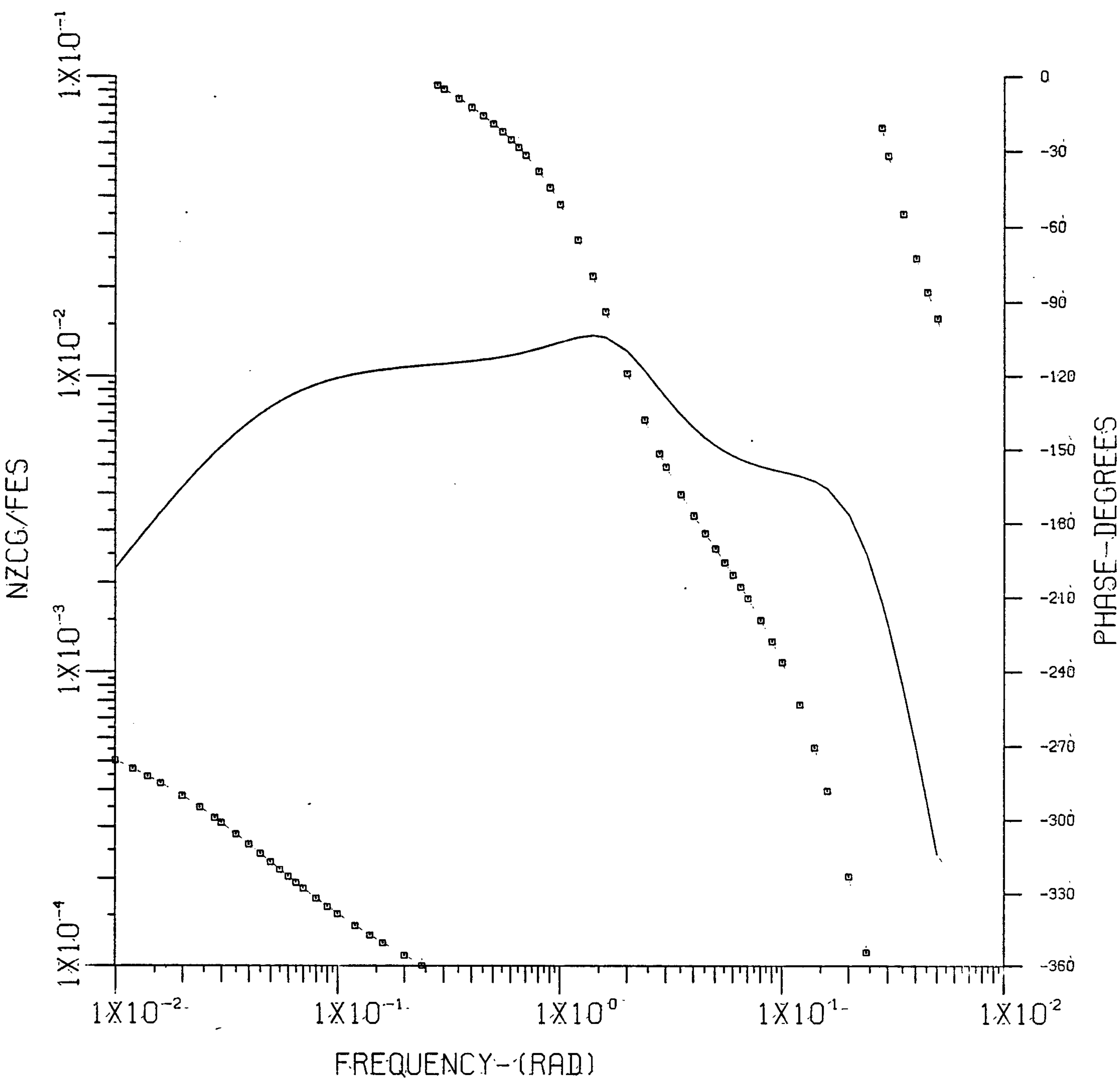

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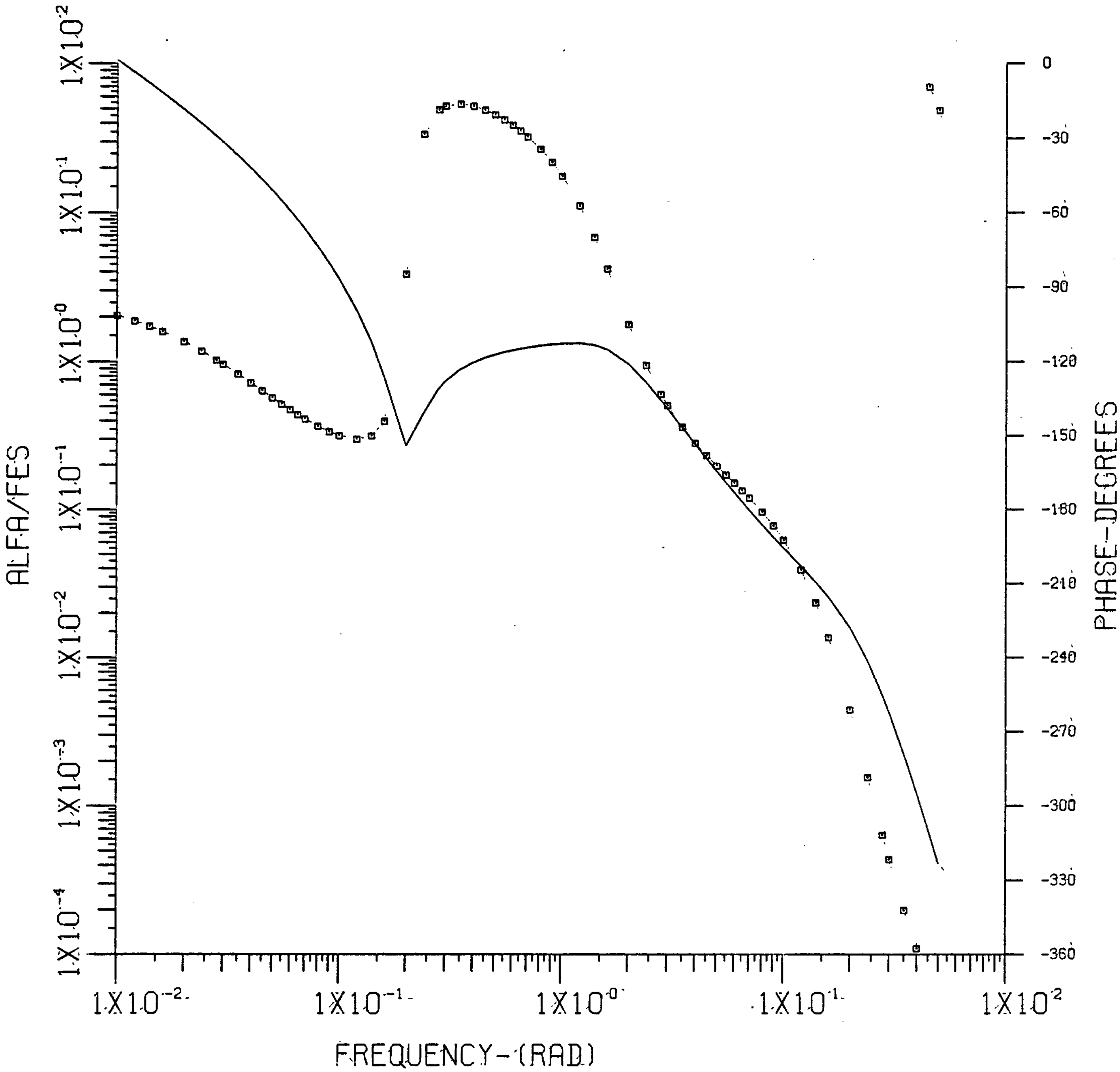

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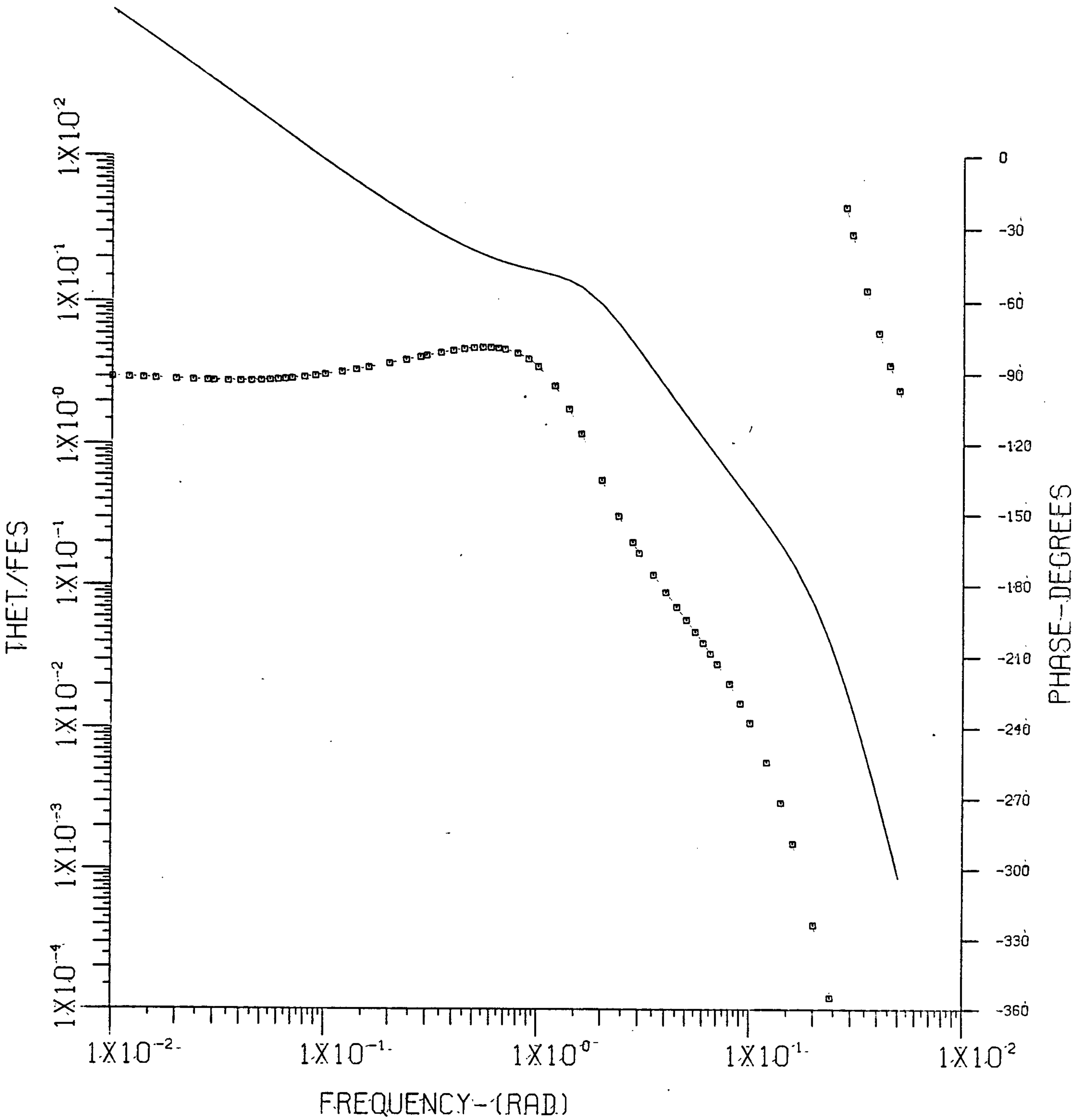

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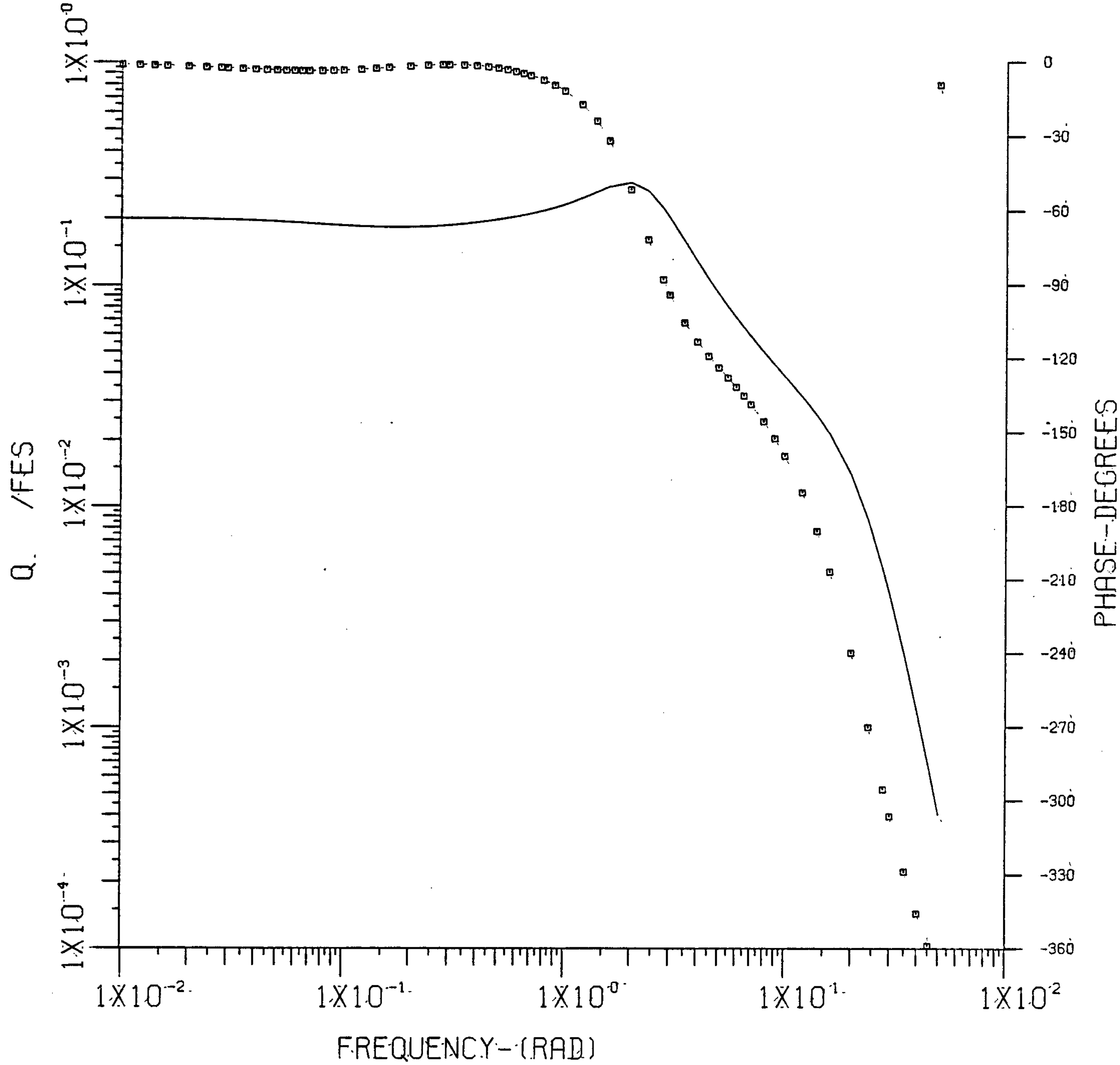

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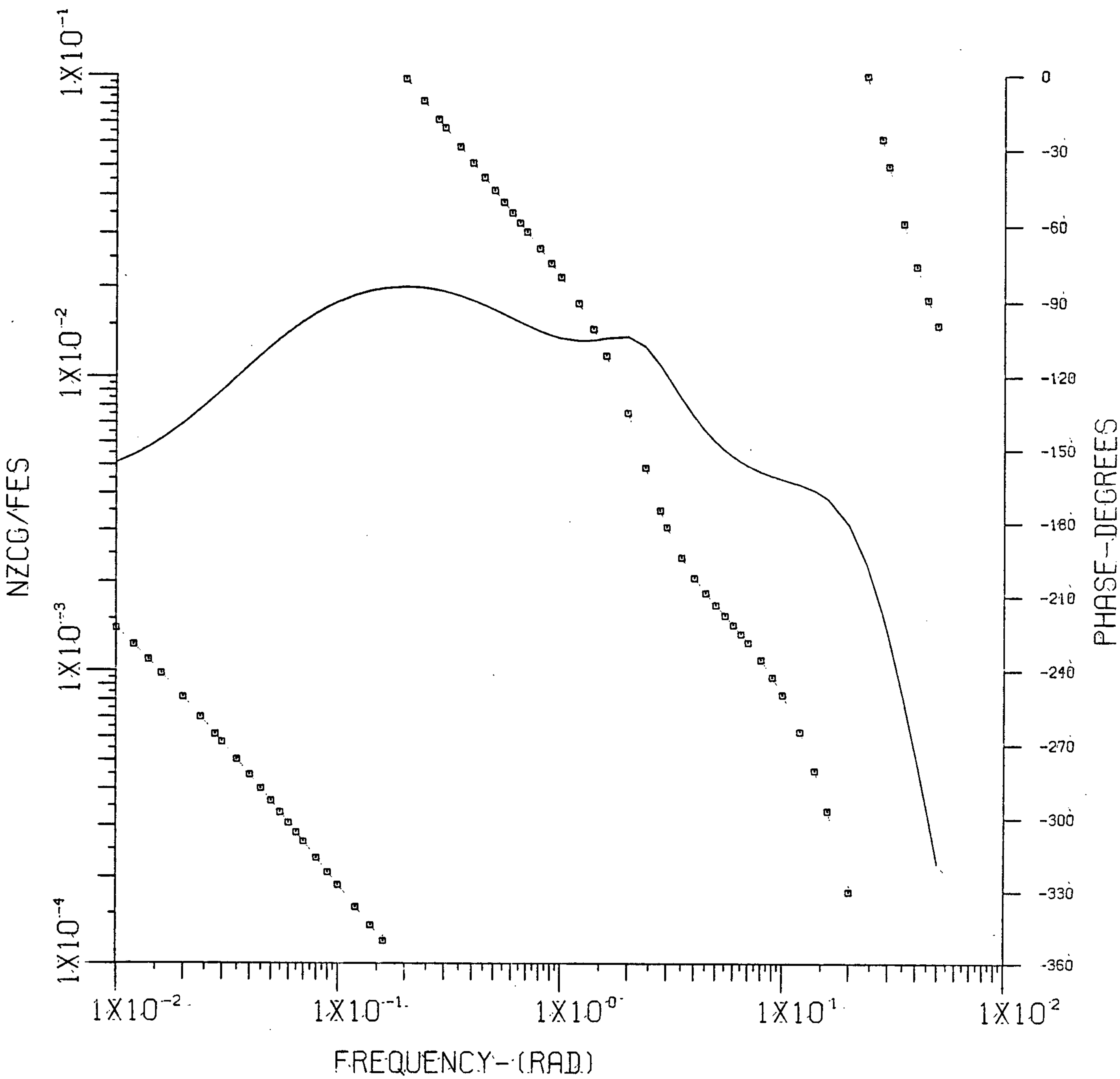

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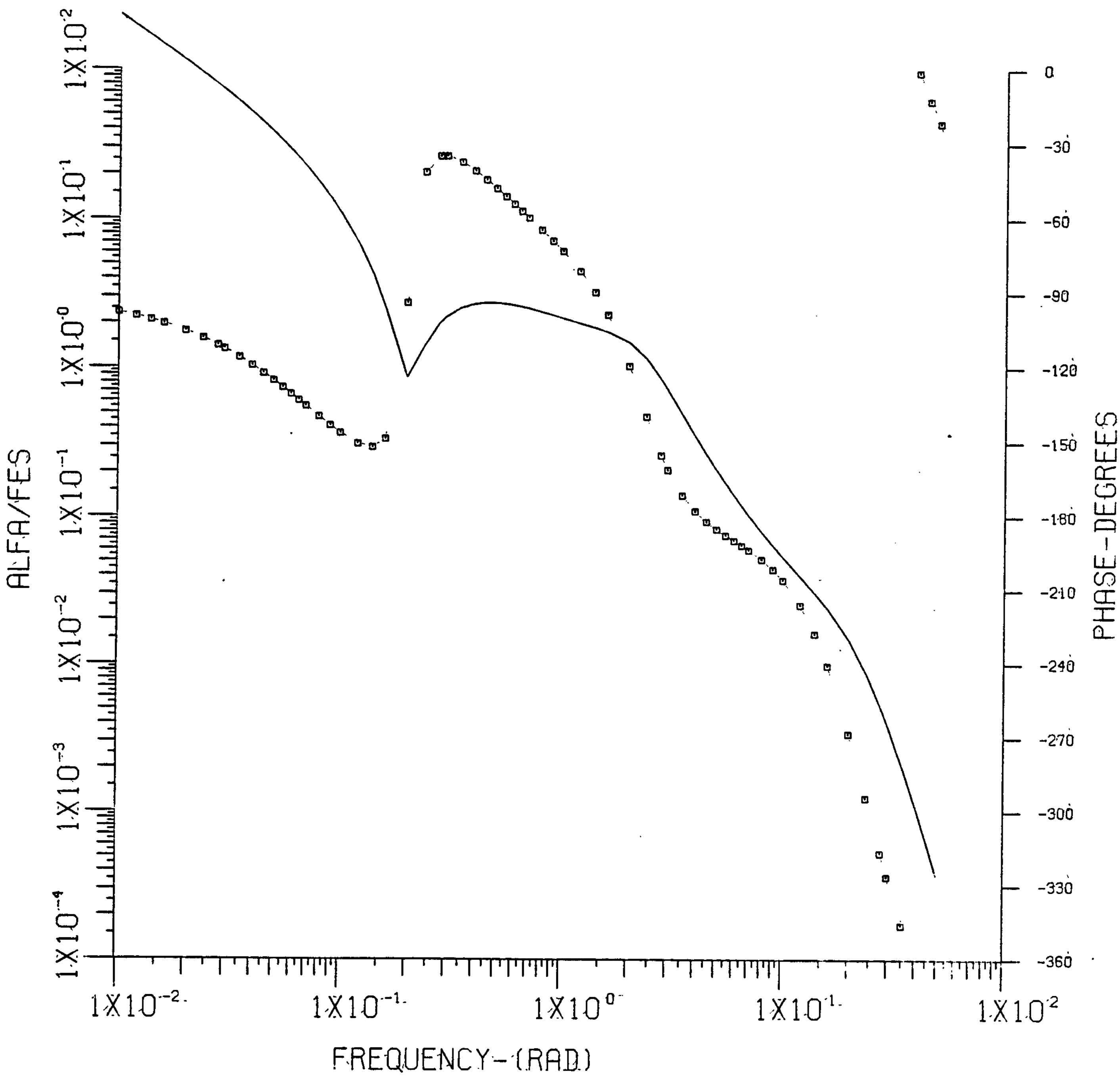

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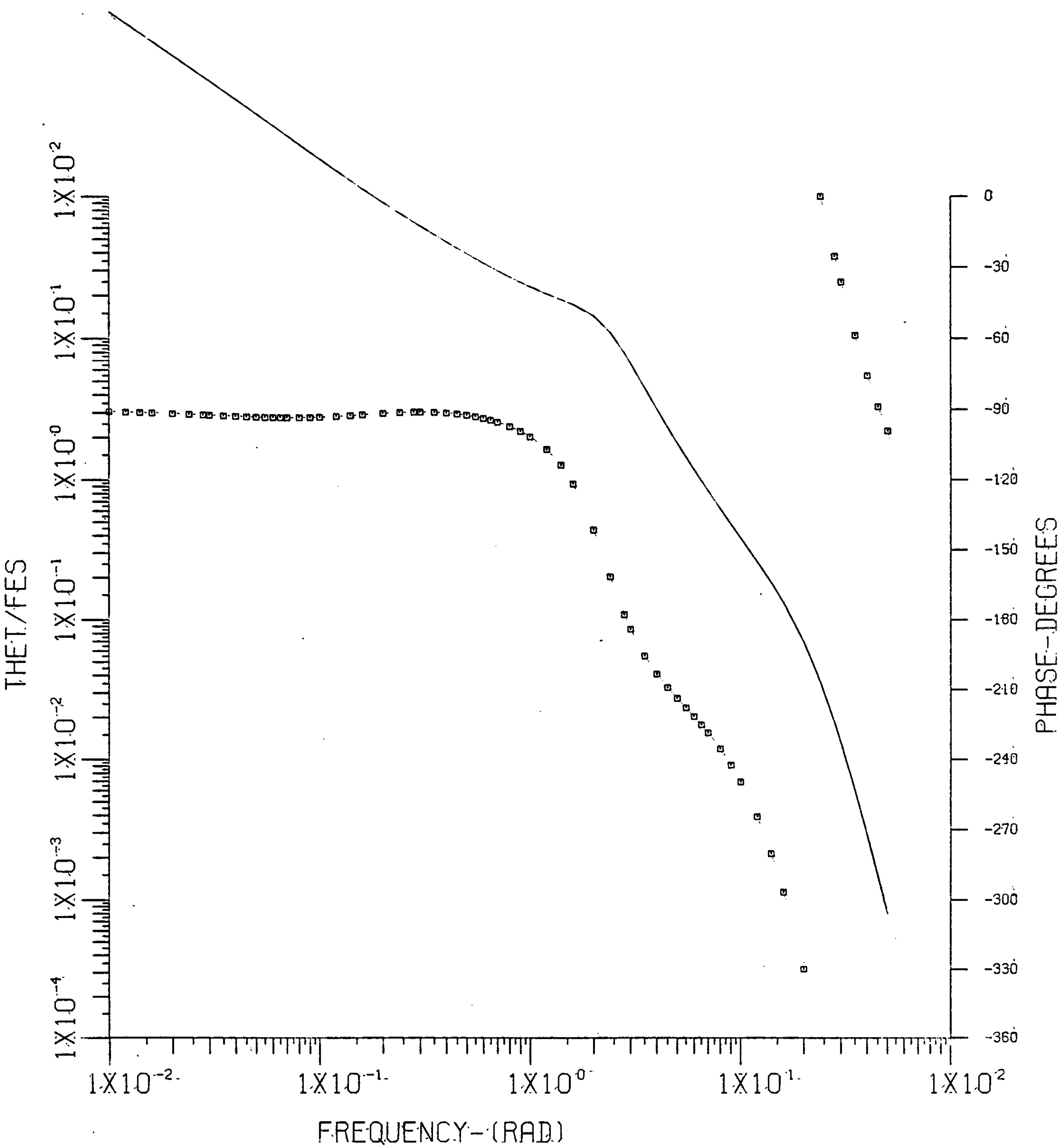

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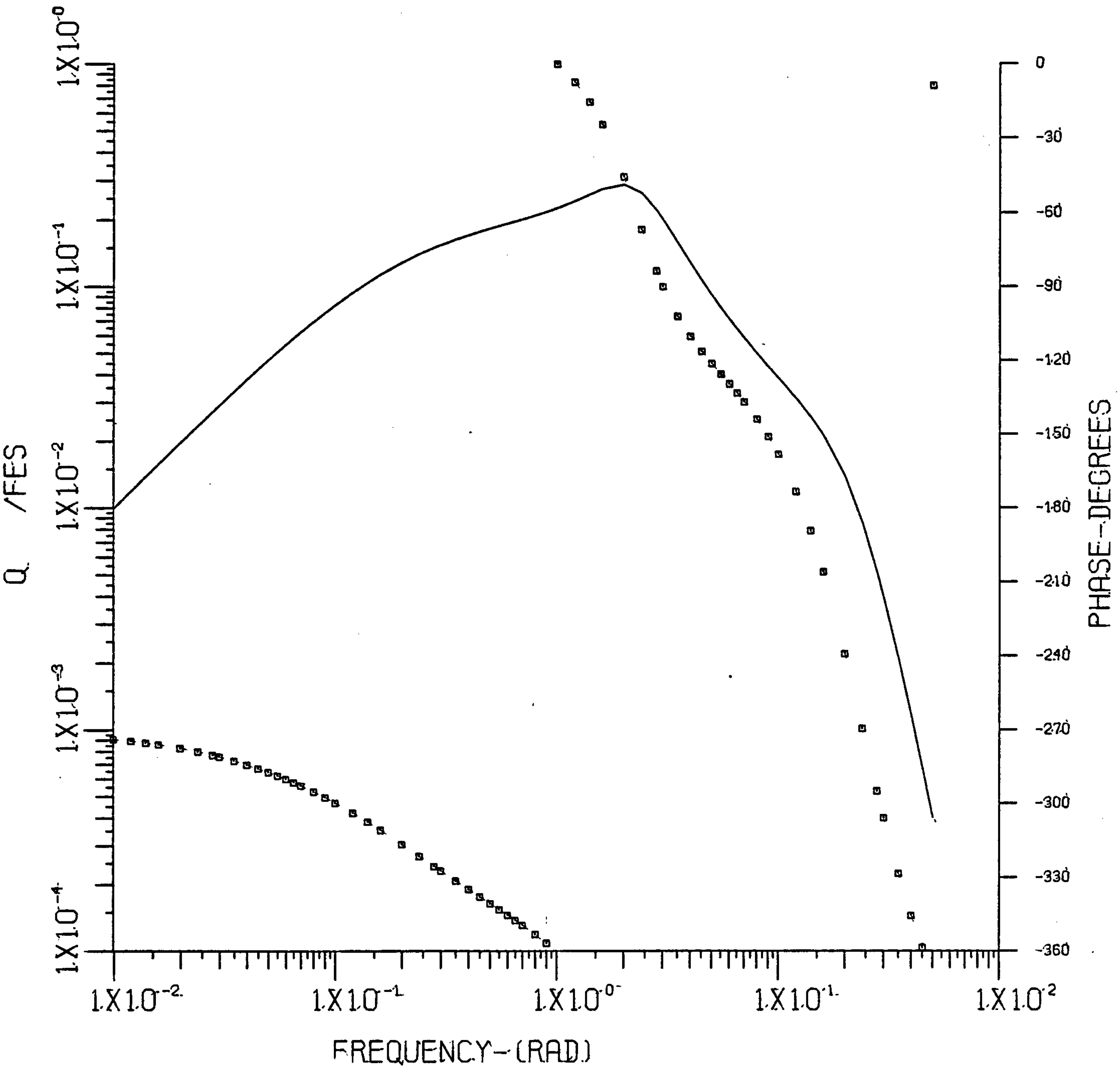

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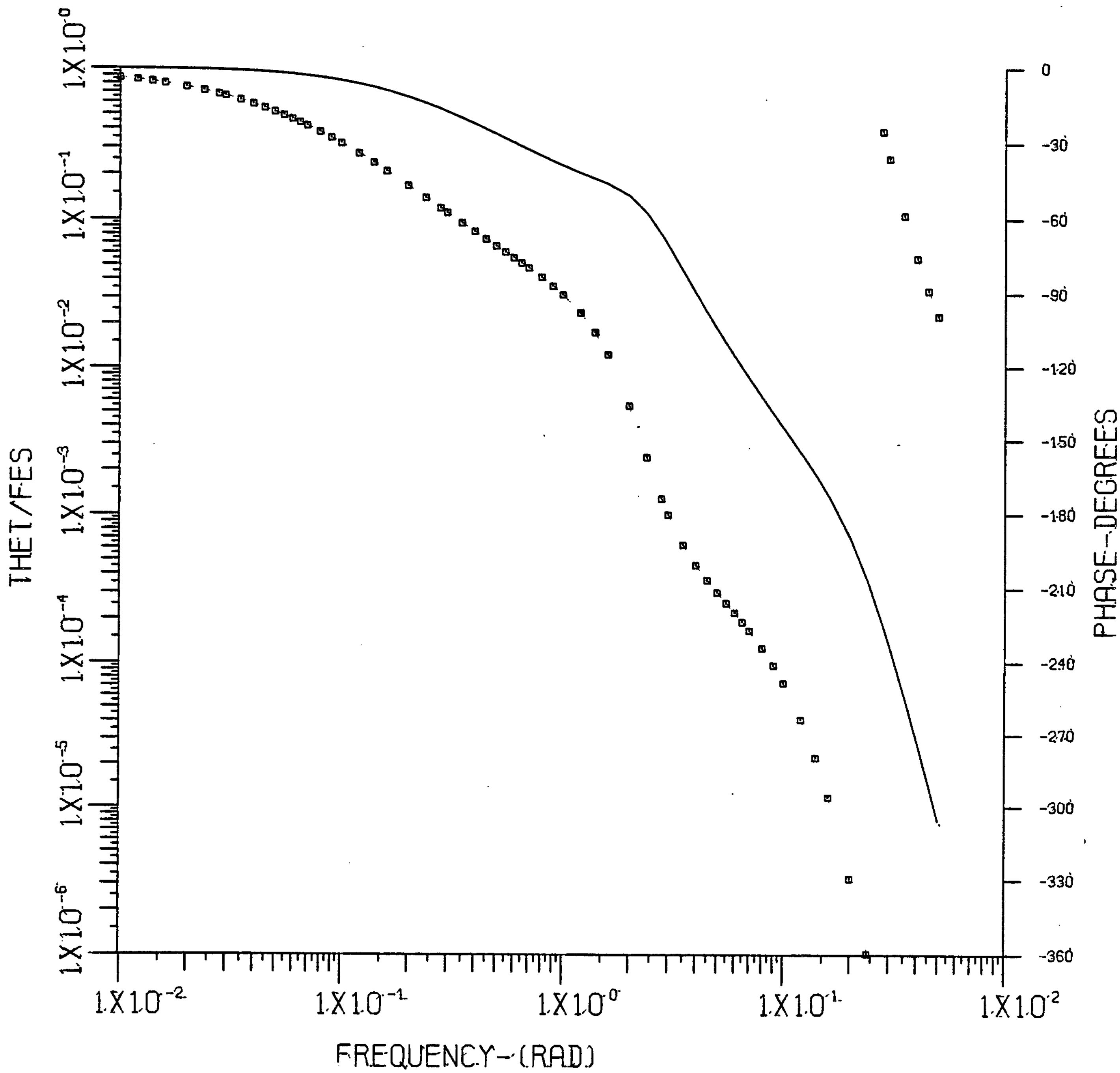

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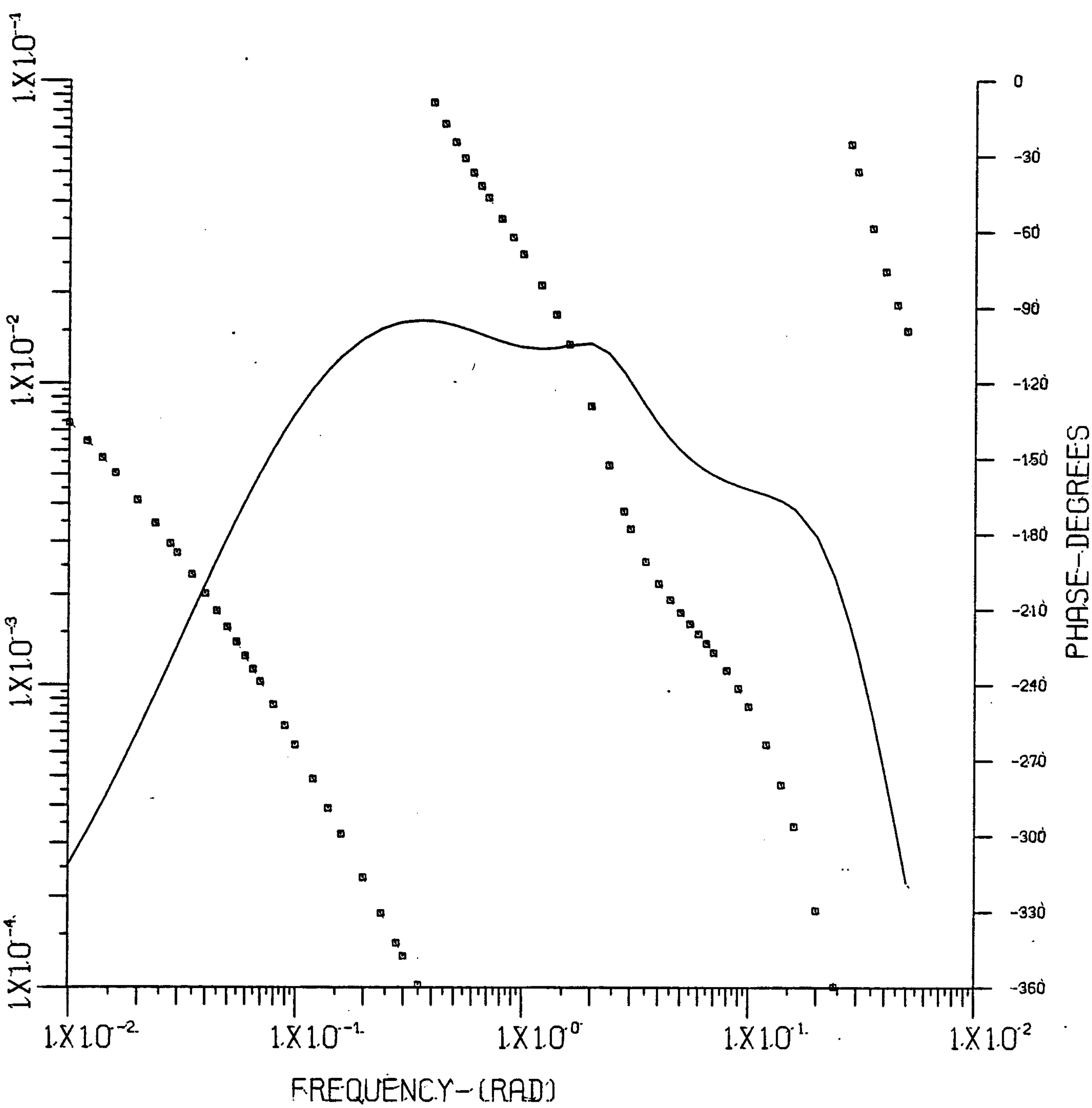

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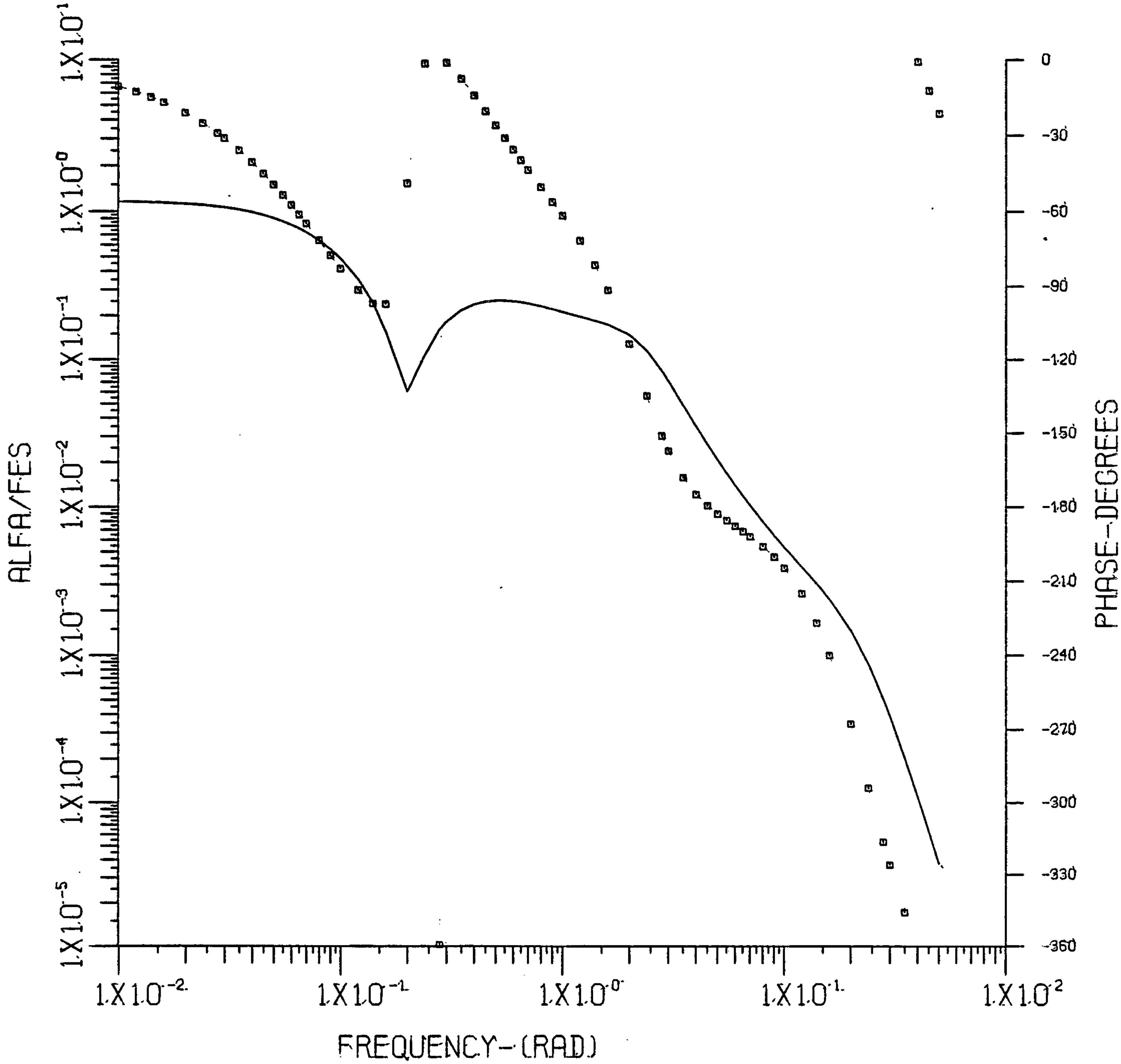

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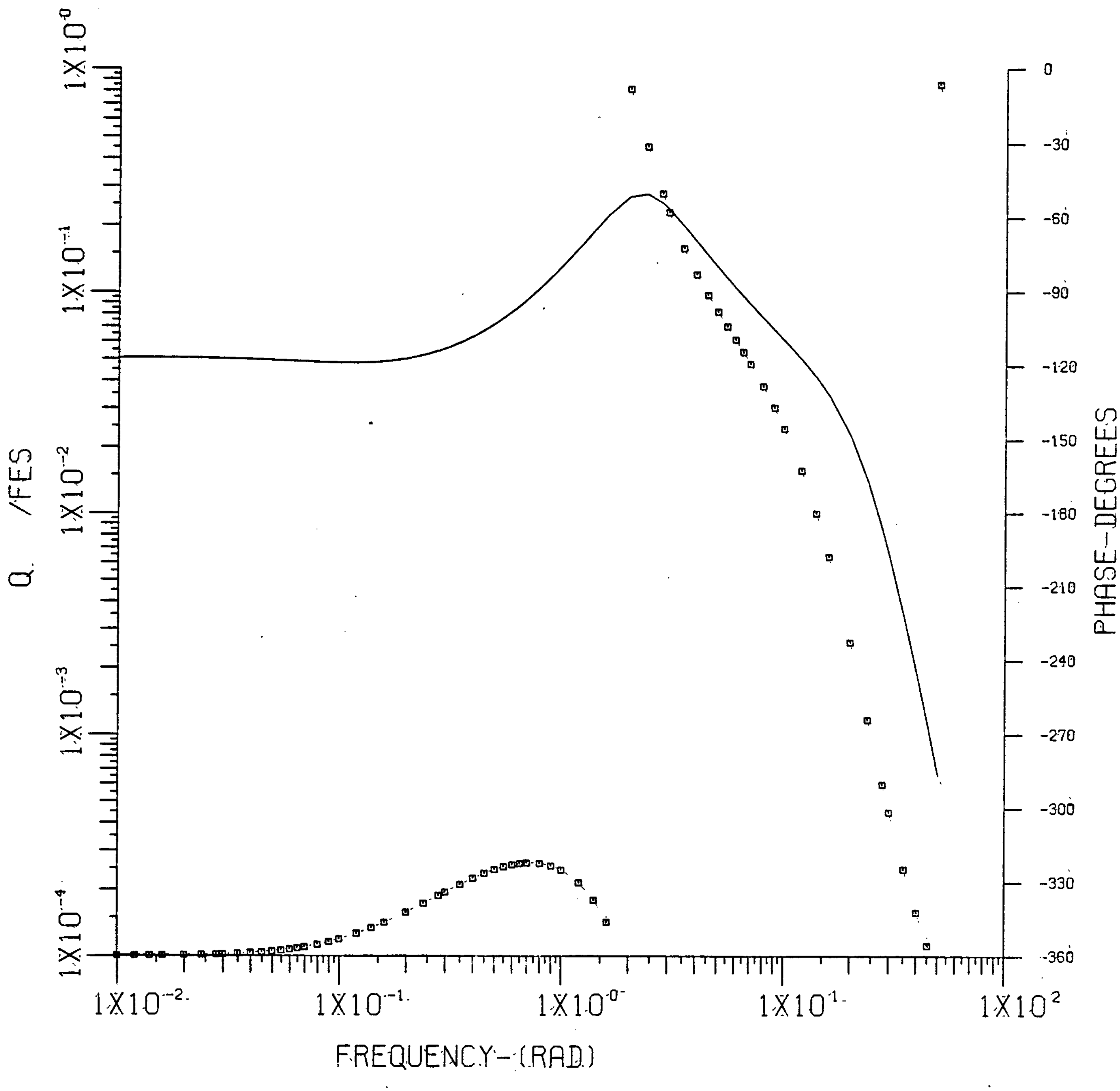

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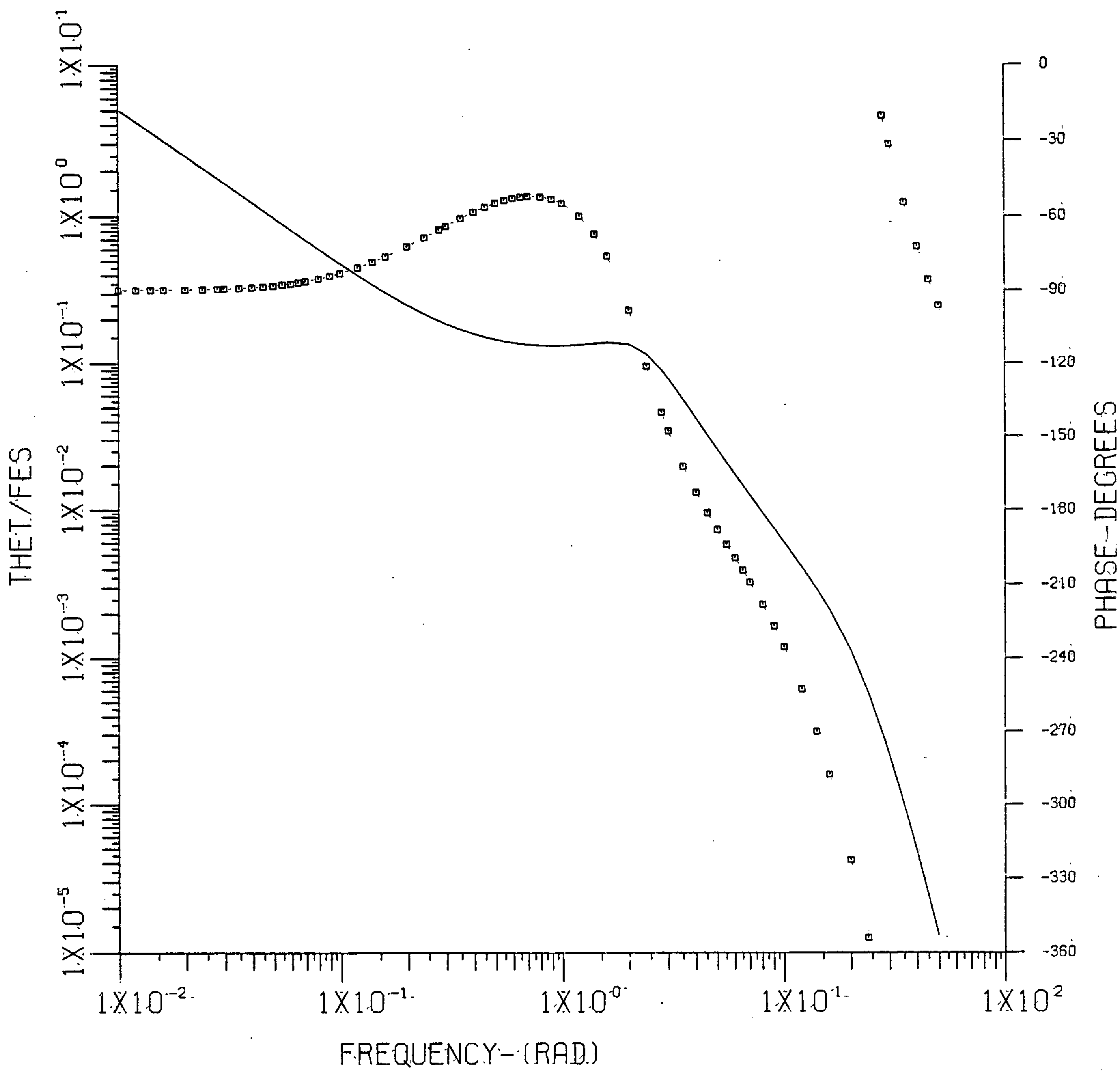
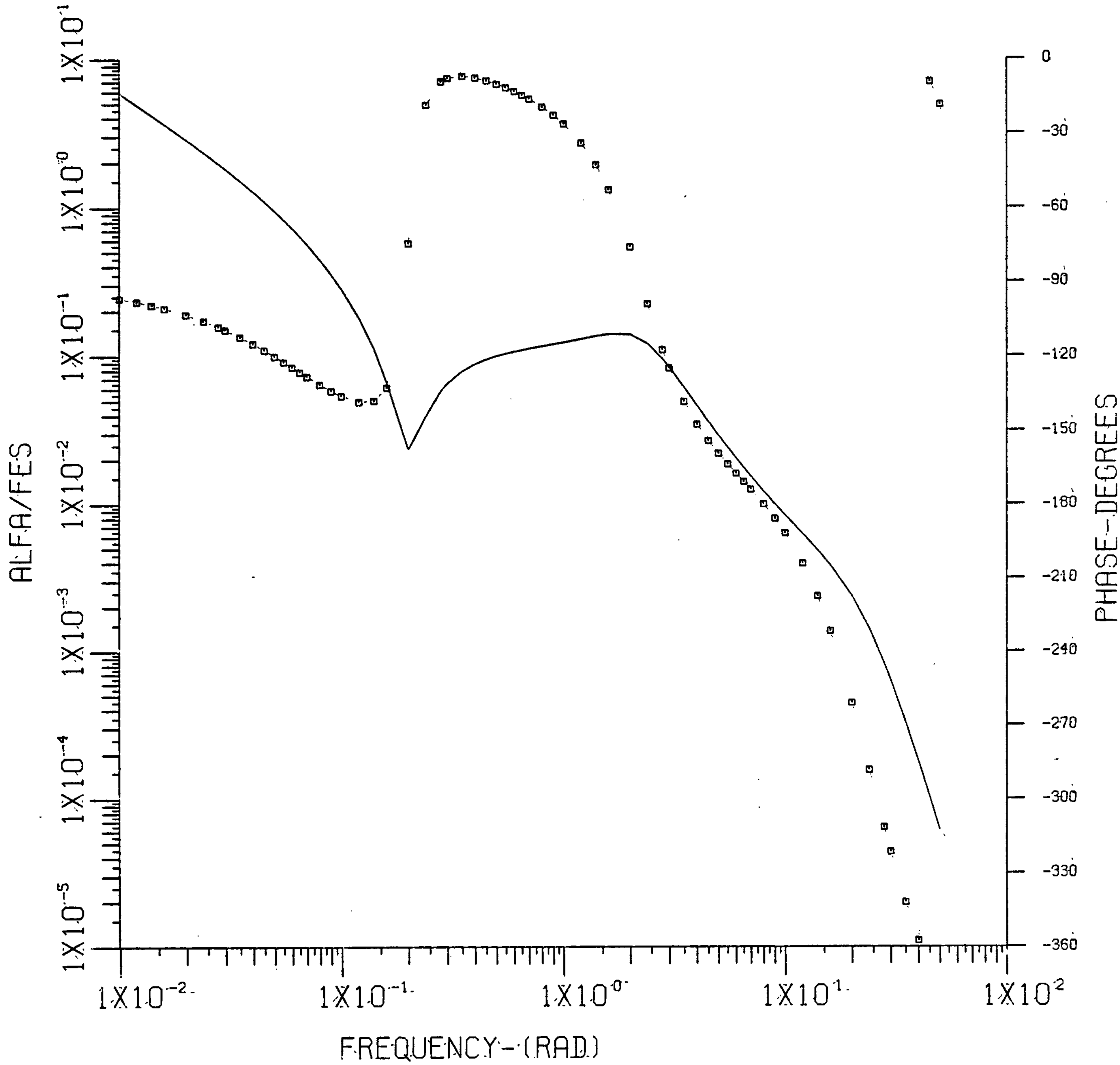
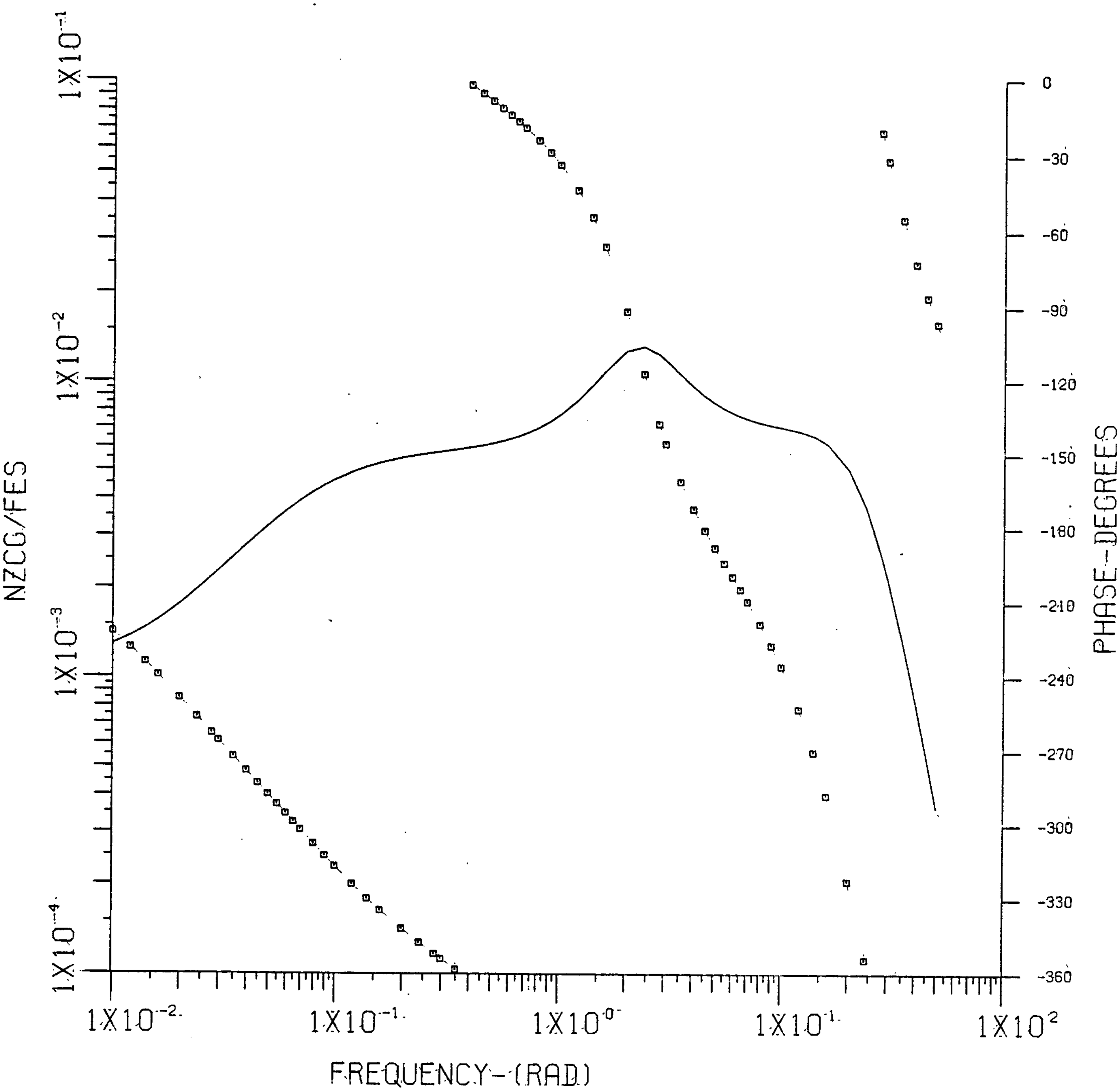


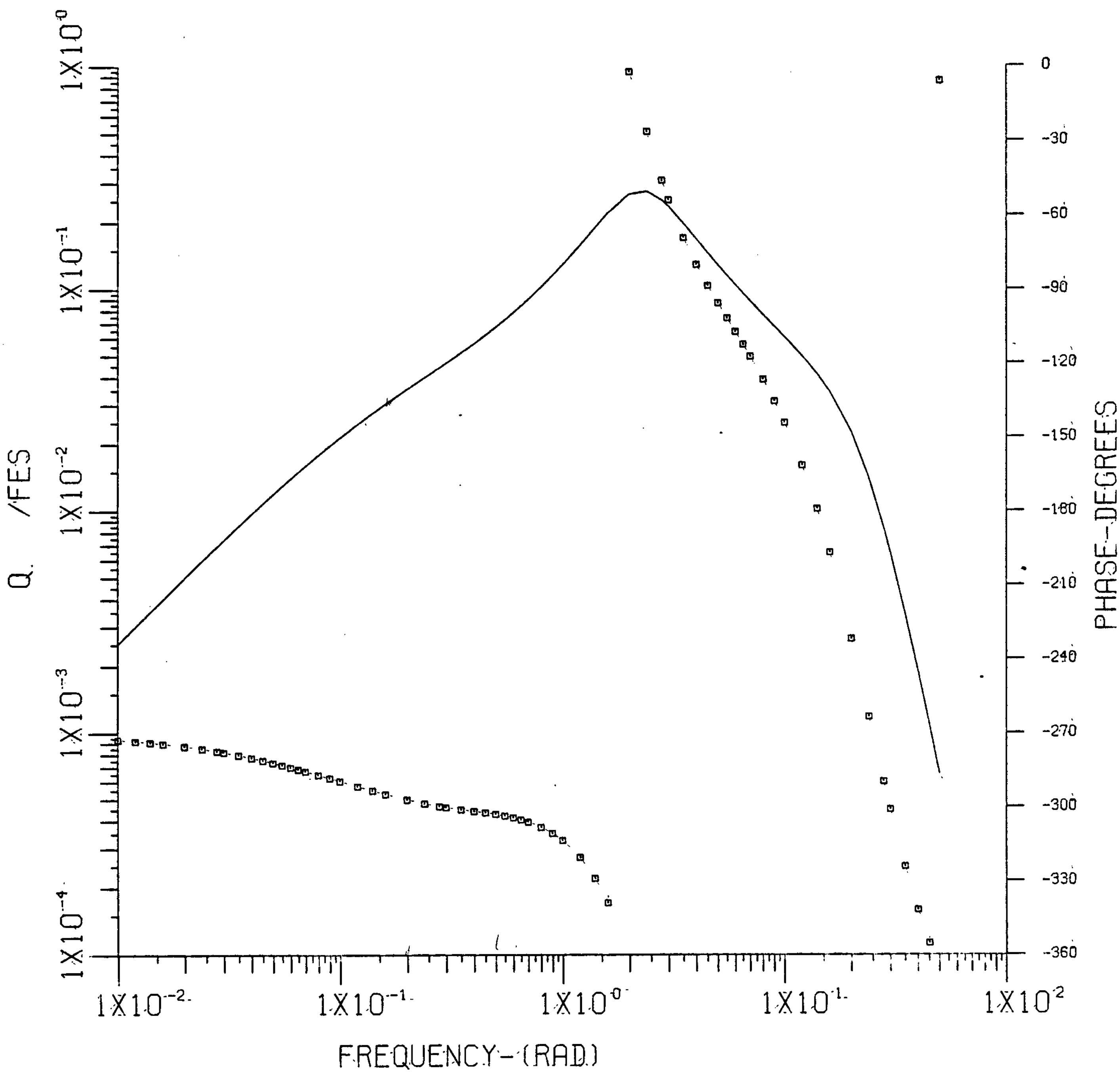
Configuration 6-2-1



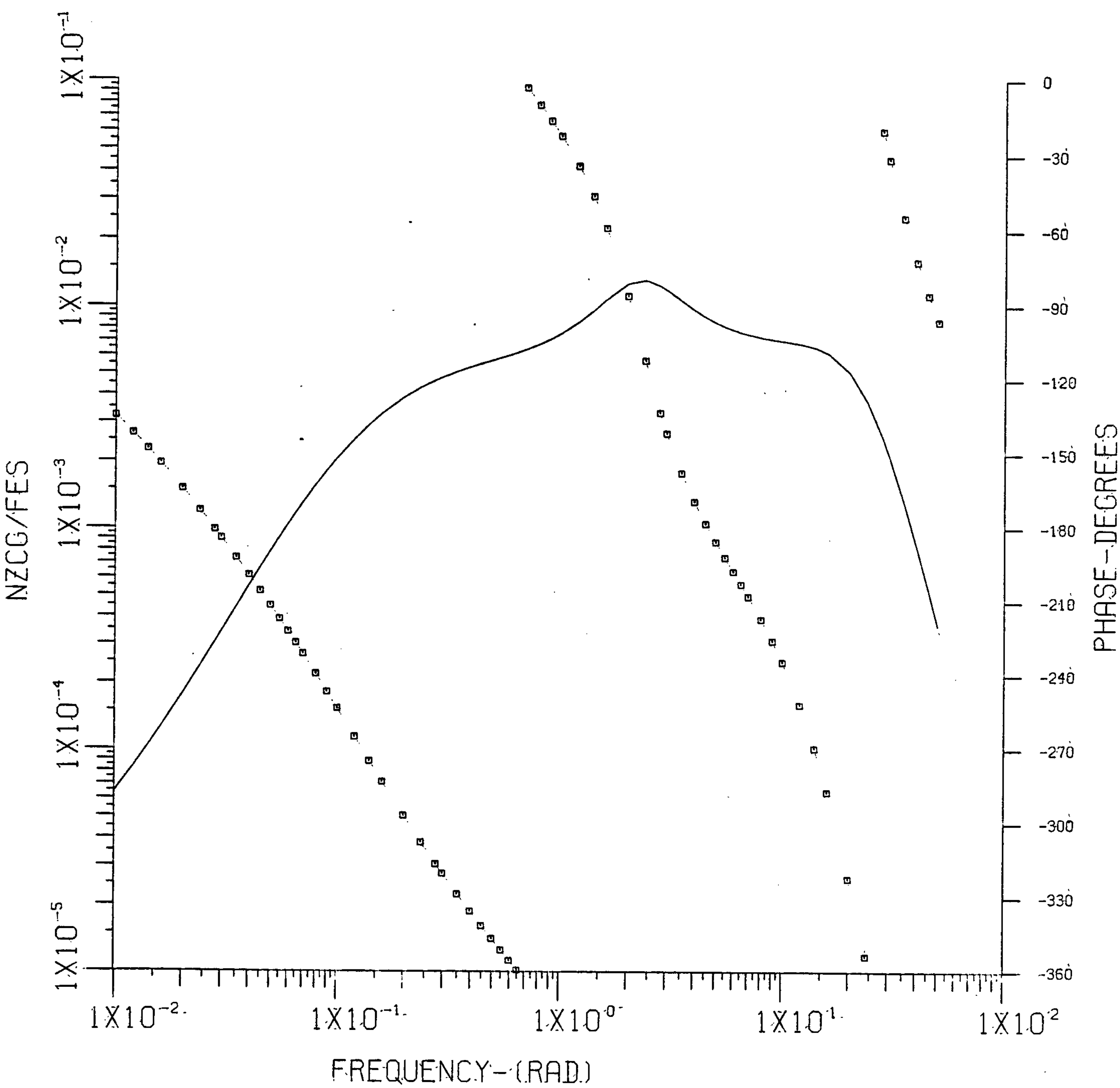
Configuration 6-2-1



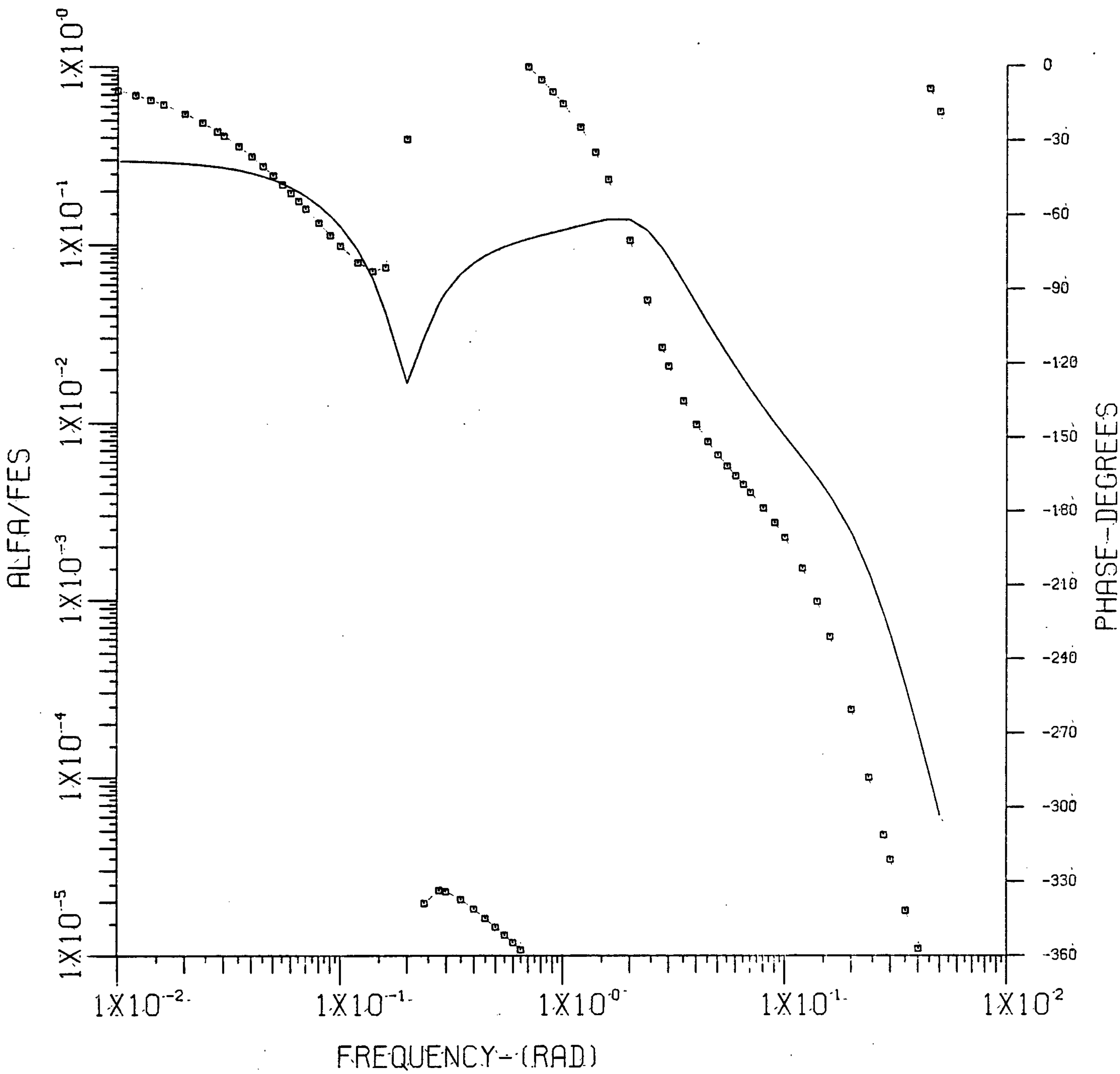
Configuration 6-2-1-1



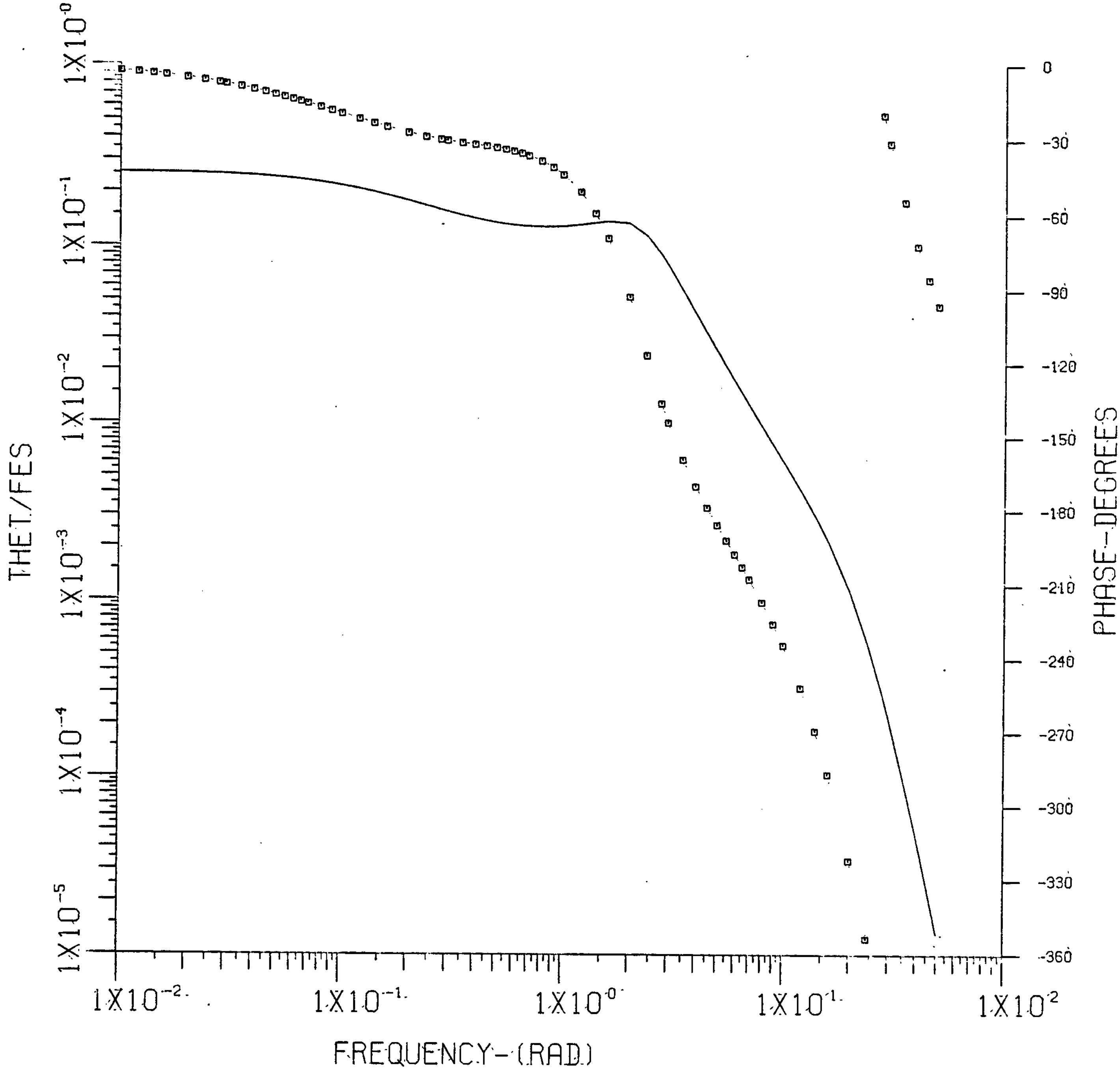
Configuration 6-2-1-1



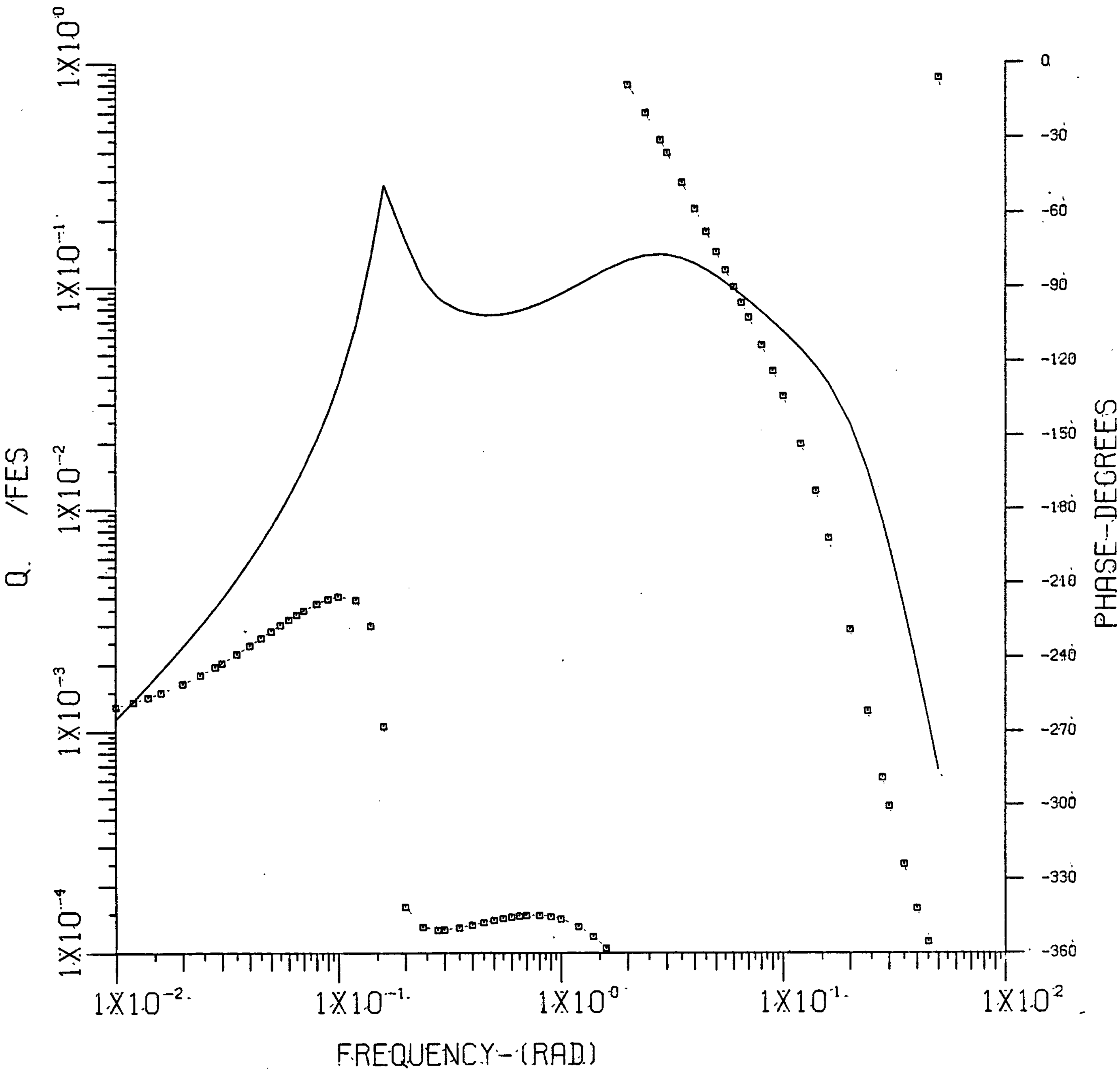
Configuration 6-2-1-1



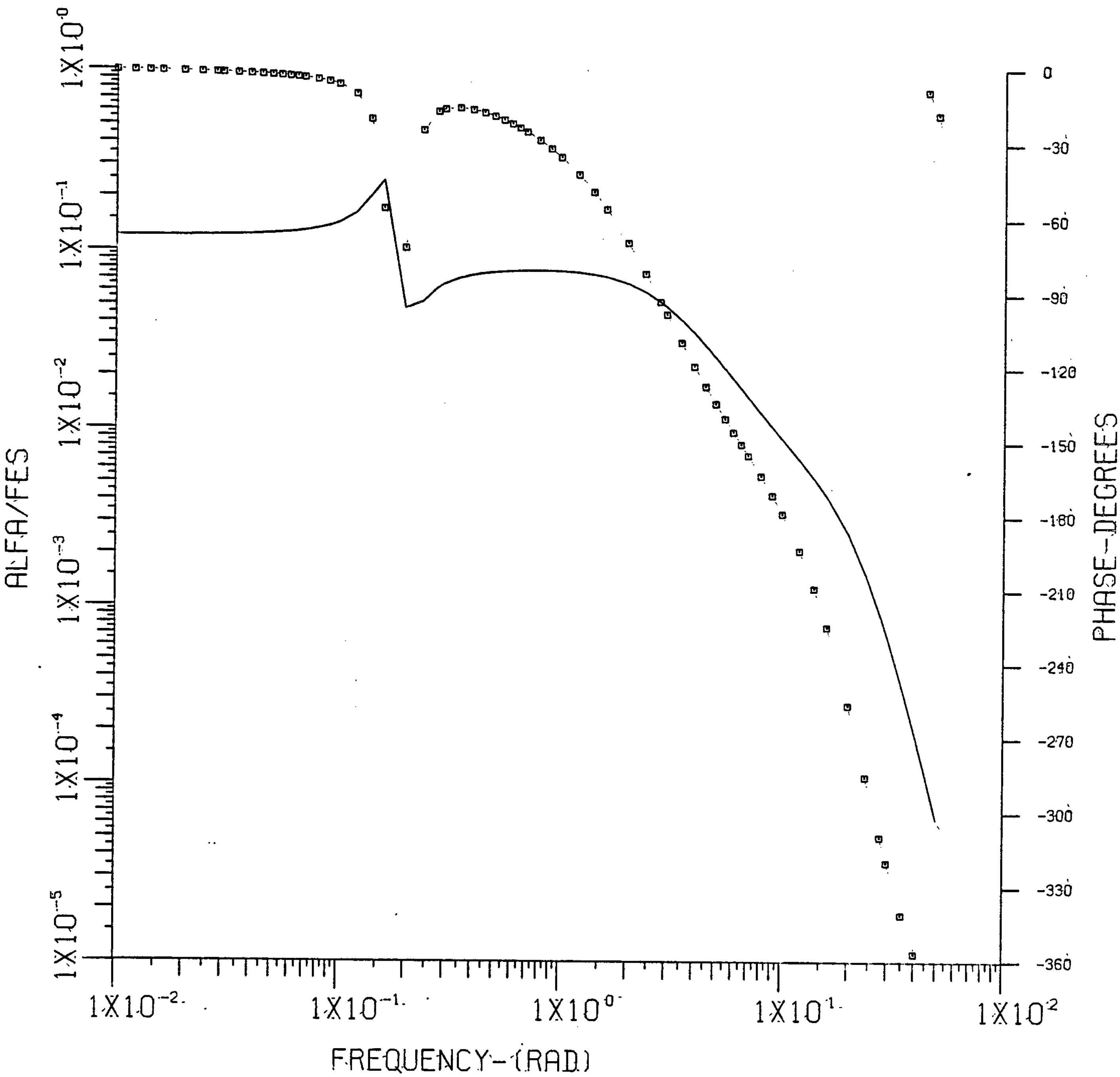
Configuration 6-2-1-1



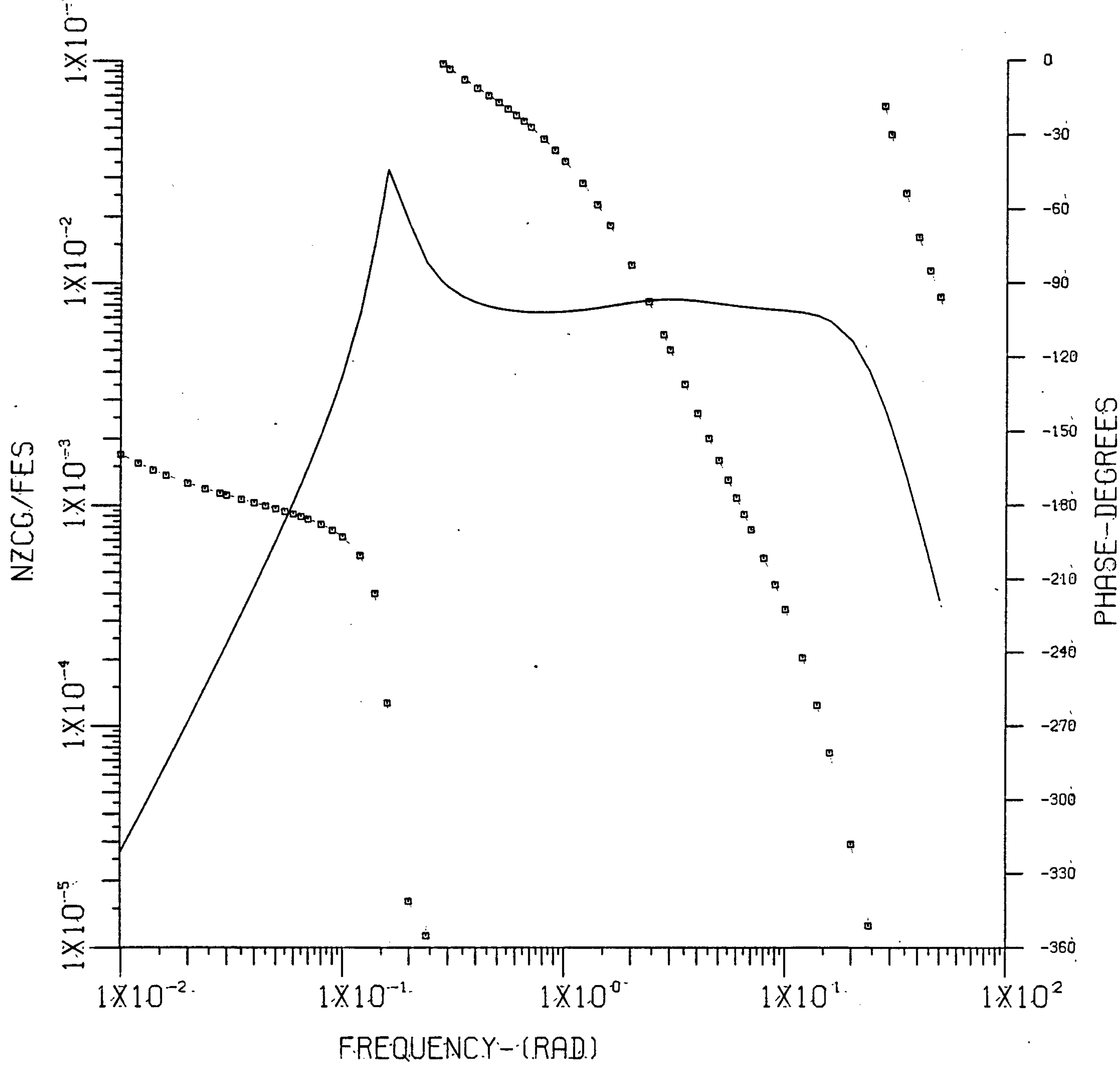
Configuration 7-1-4



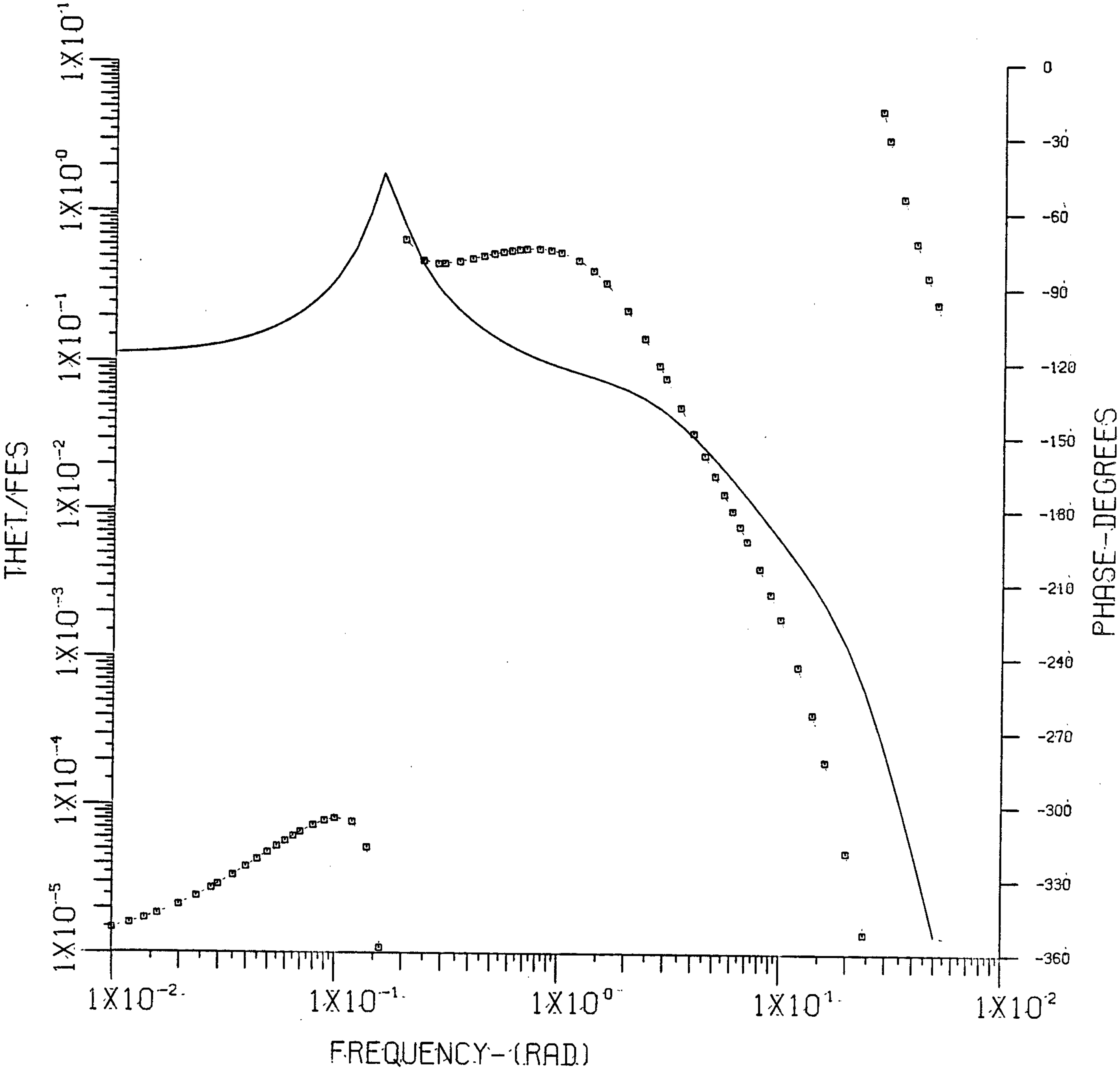
Configuration 7-1-4



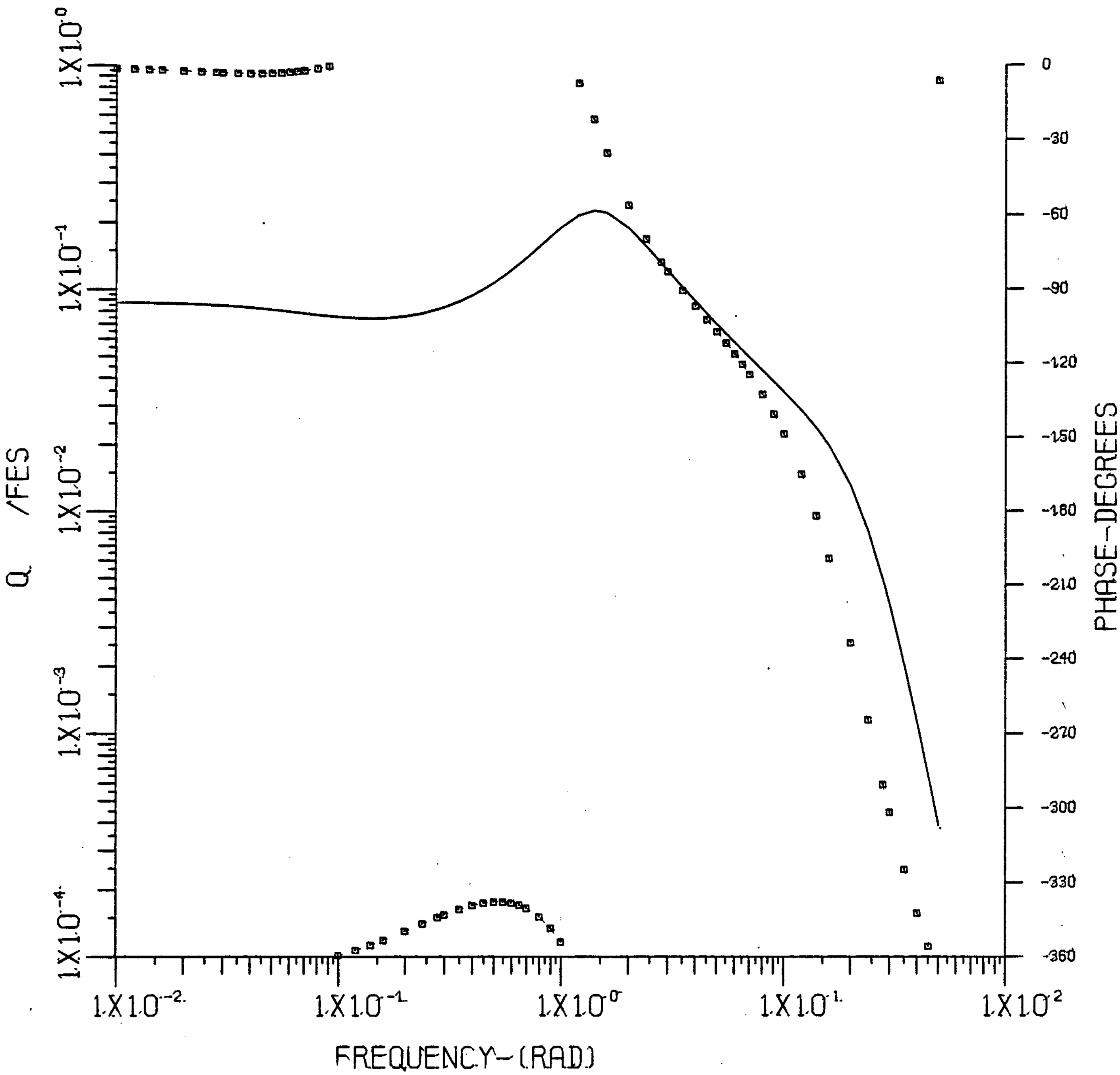
Configuration 7-1-4



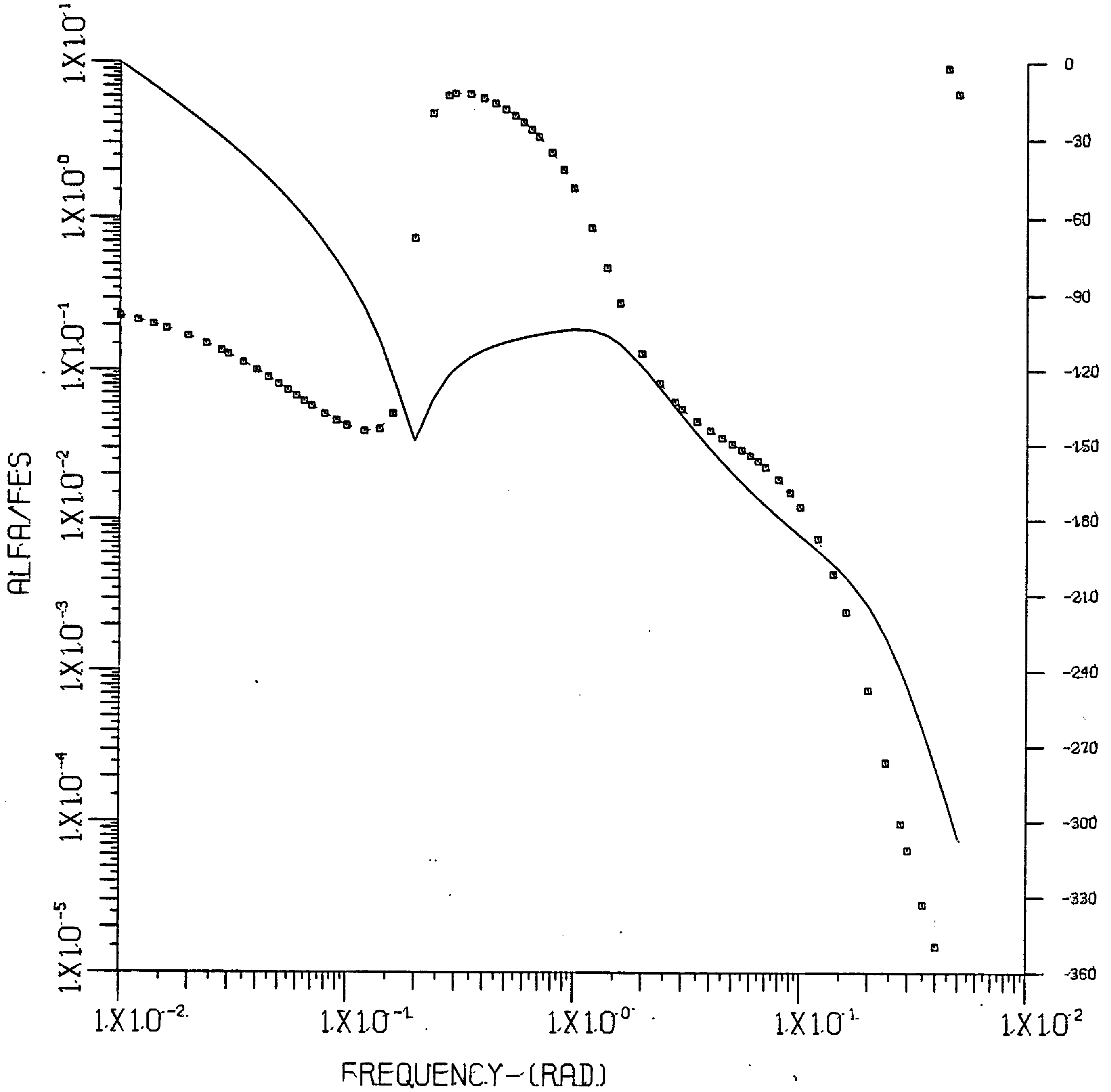
Configuration 7-1-4



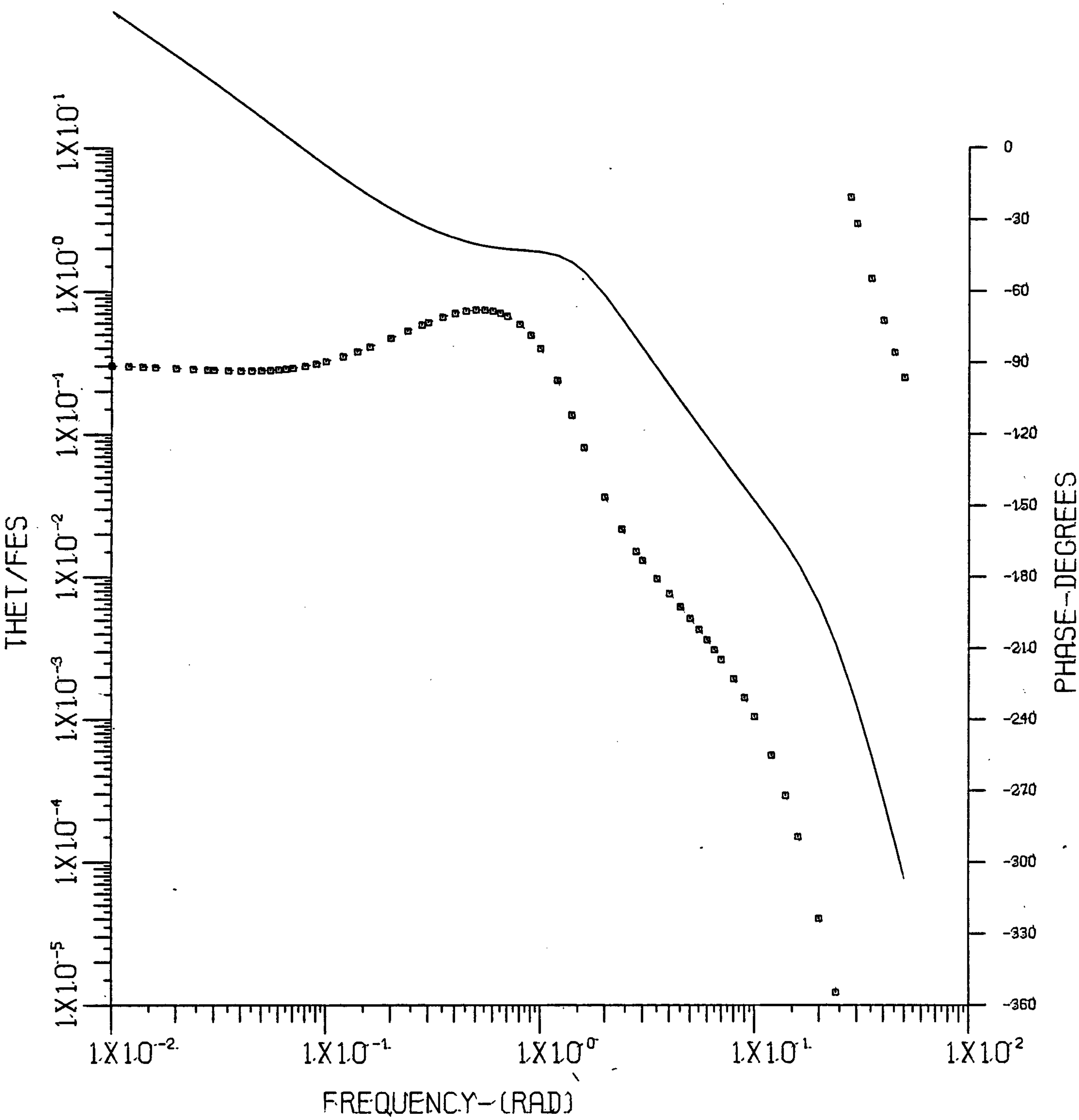
Configuration 8-1-5



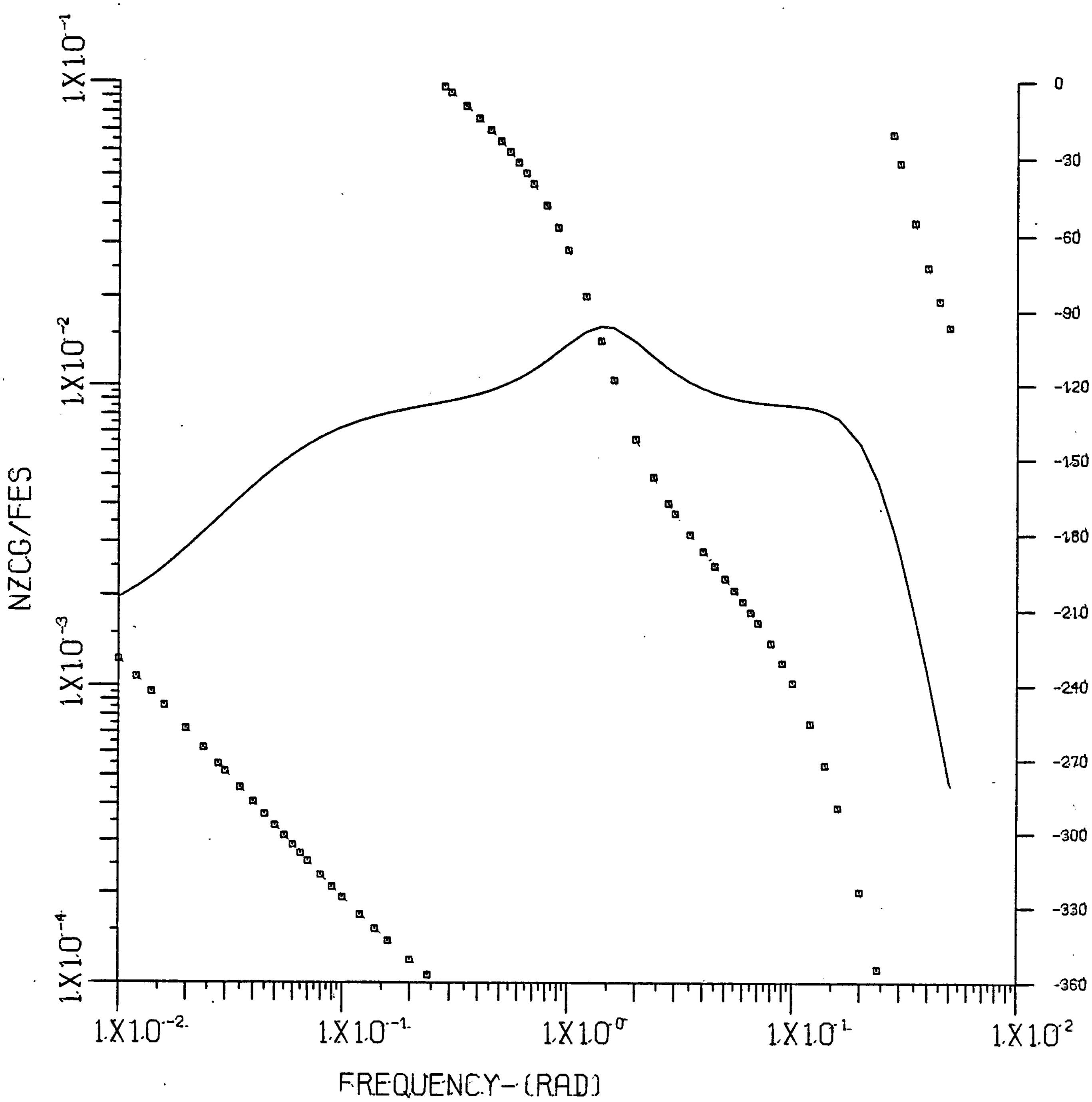
Configuration 8-1-5



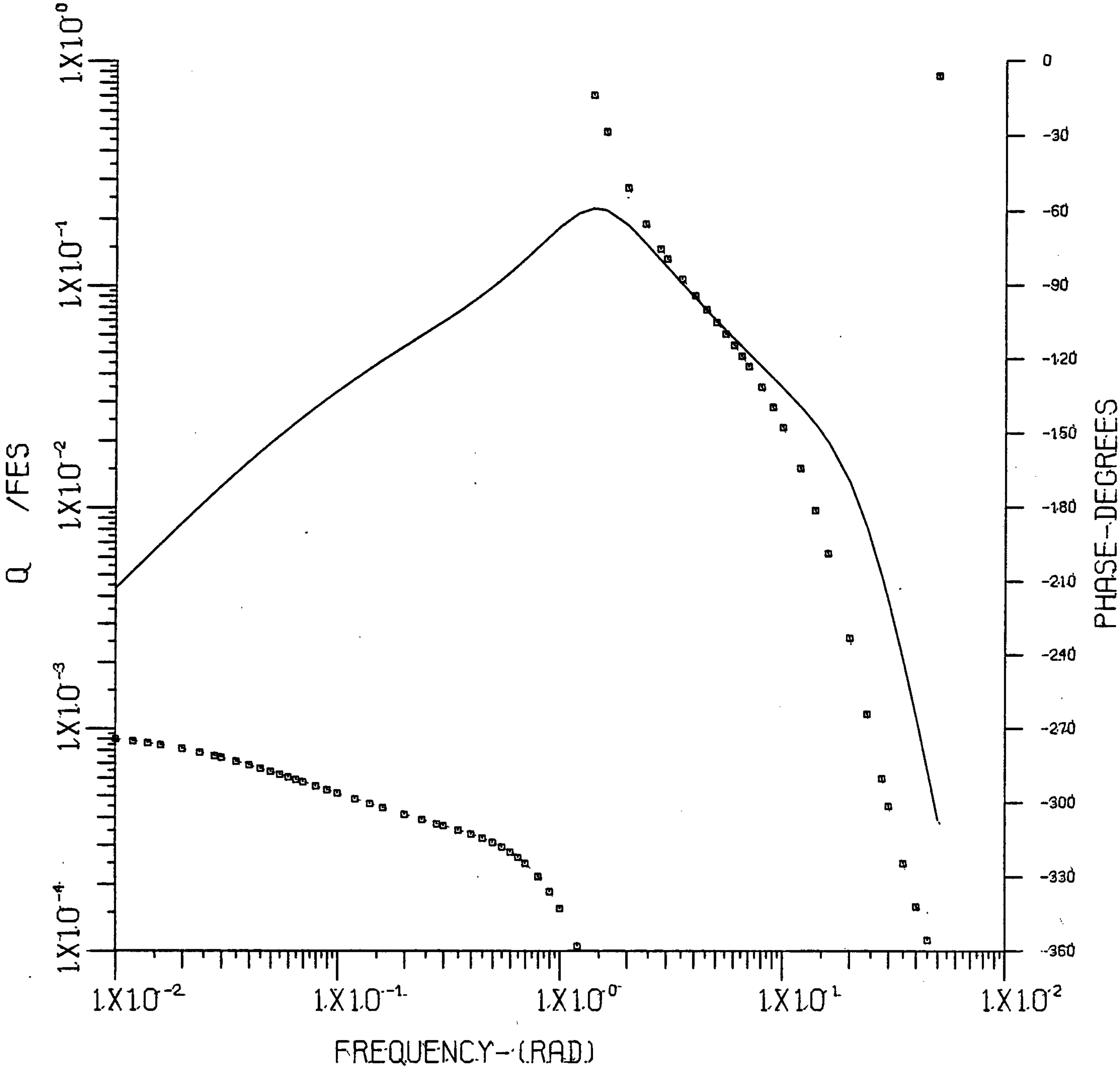
Configuration 8-1-5



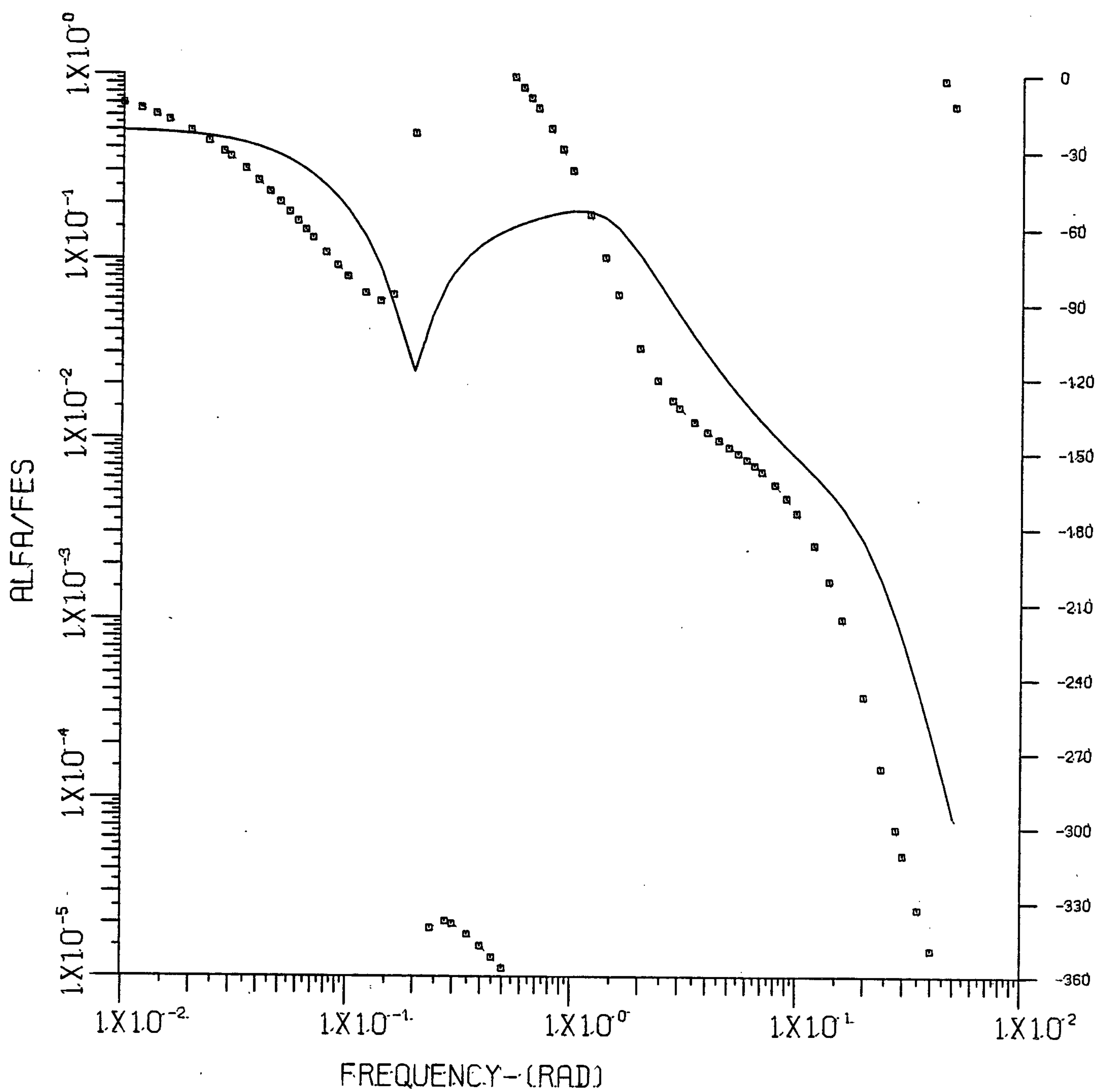
Configuration 8-1-5



Configuration 8-1-5-1



Configuration 8-1-5-1



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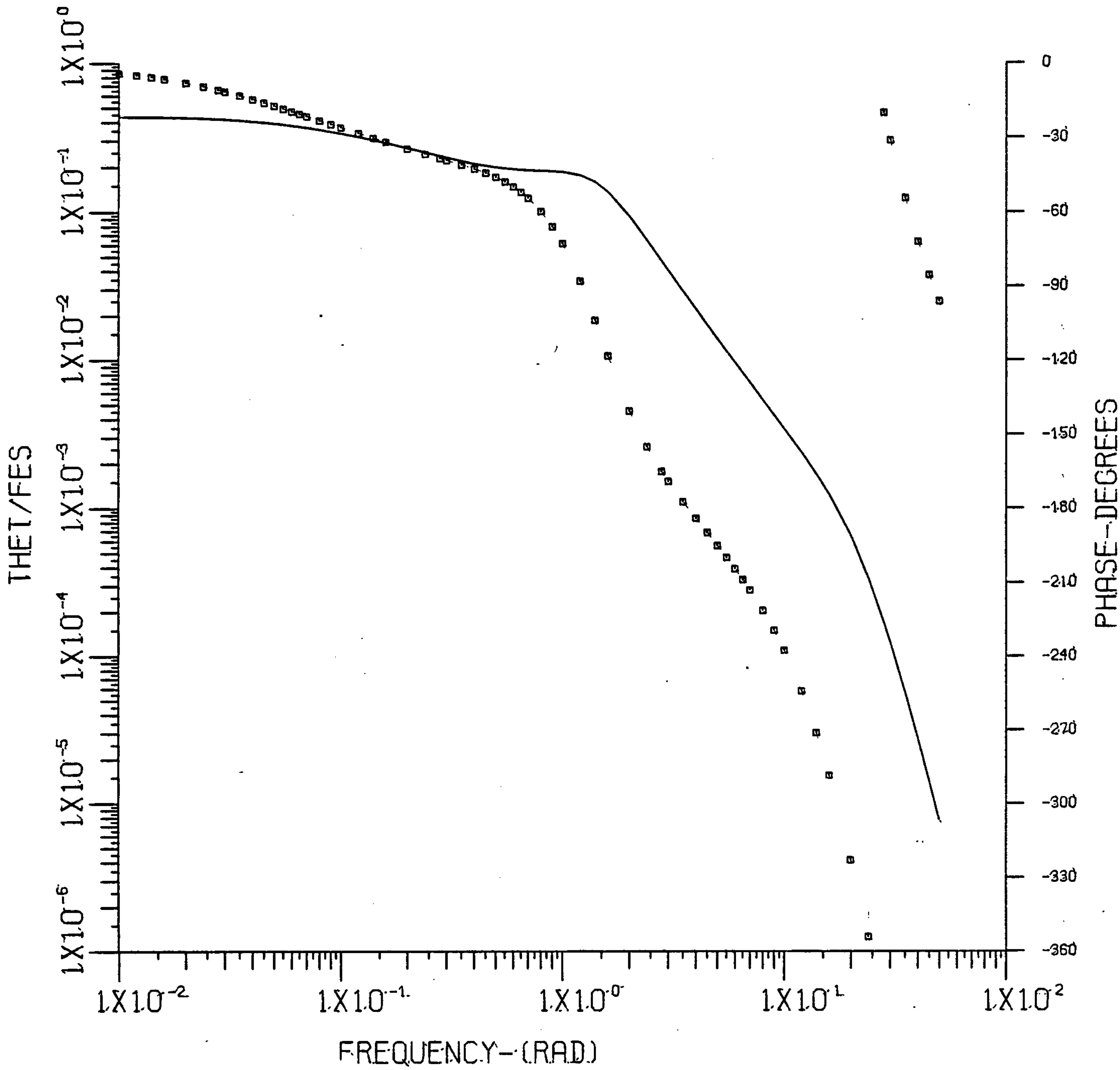
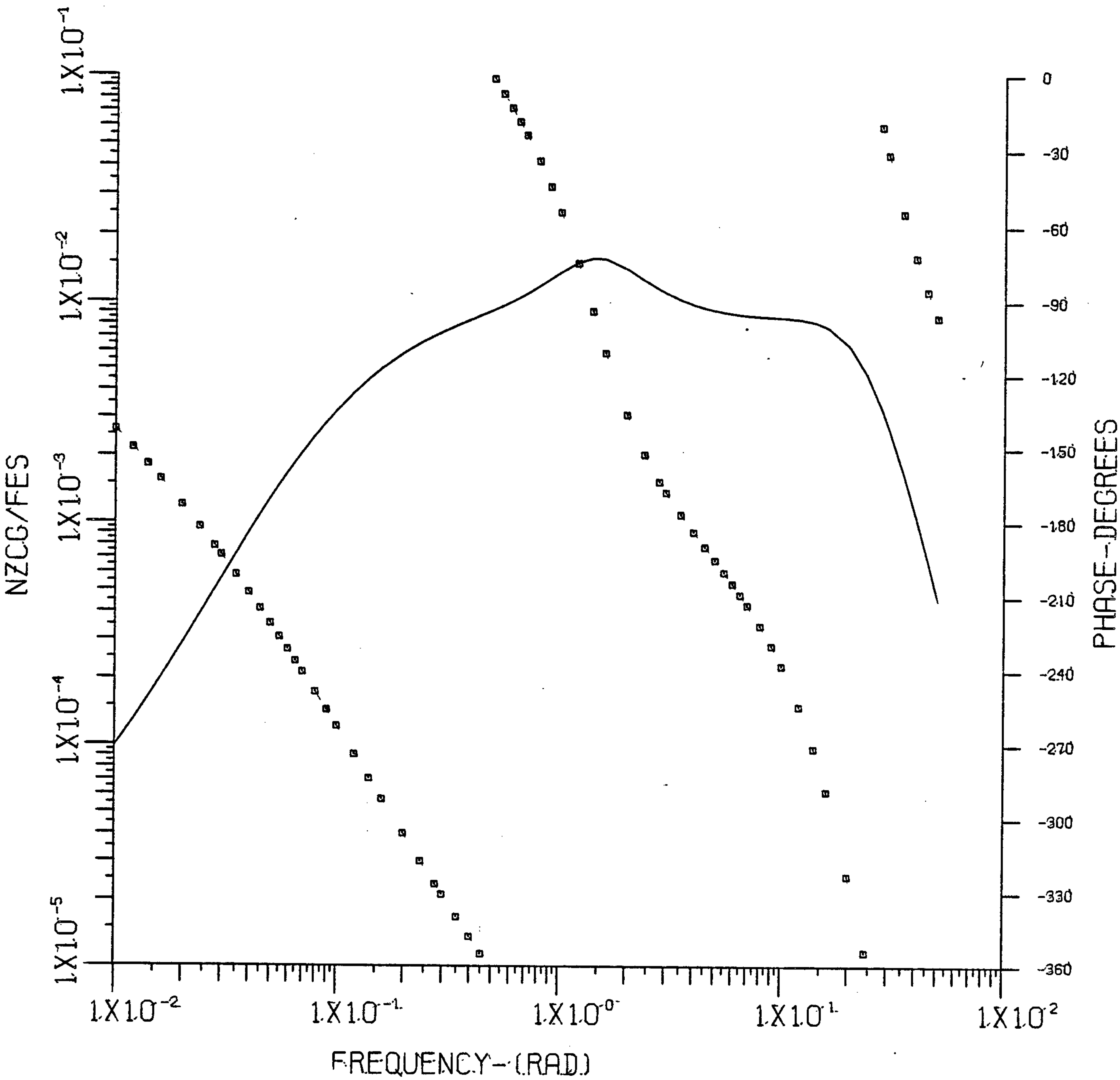


Configuration 8-1-5-1



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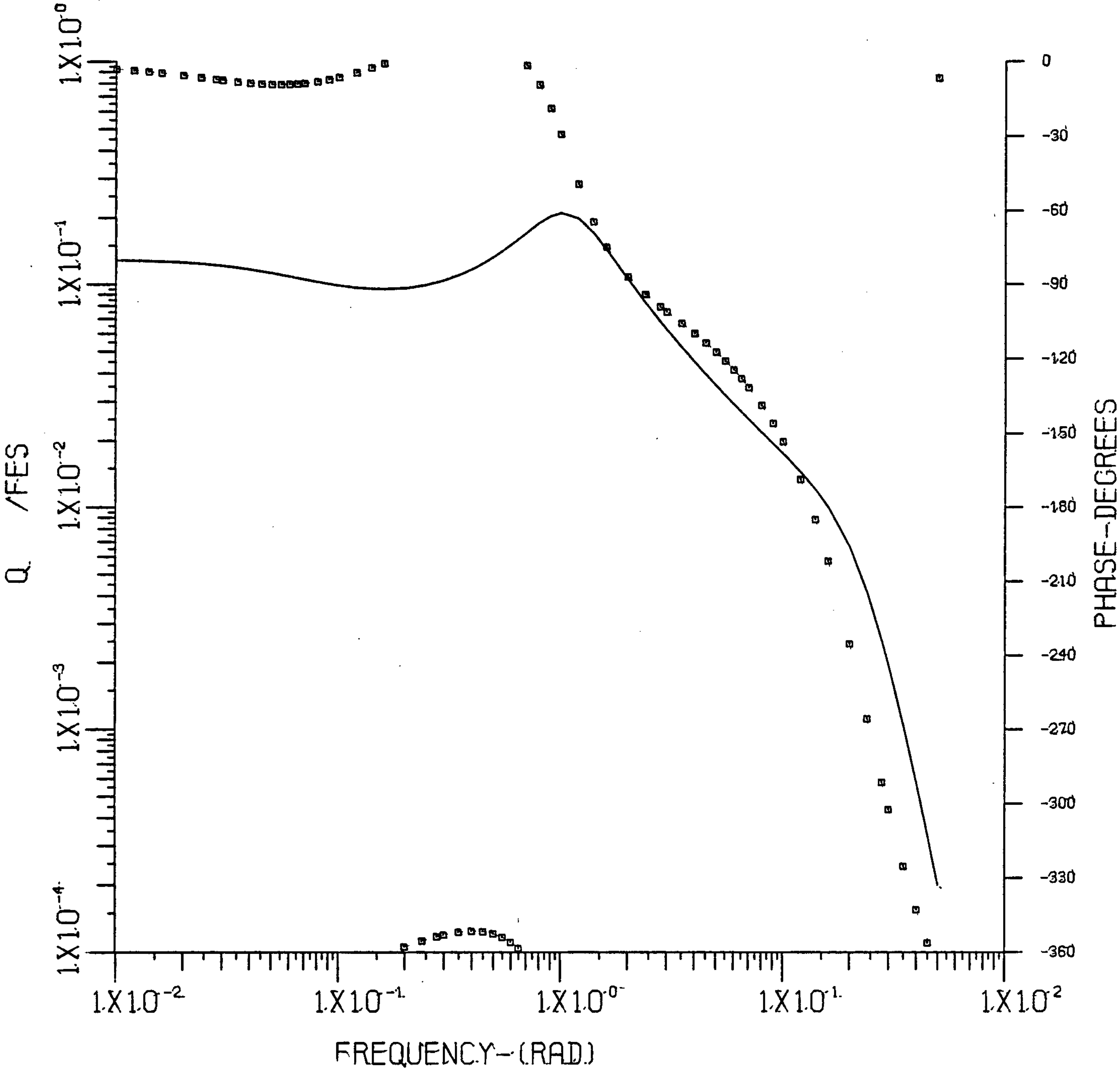
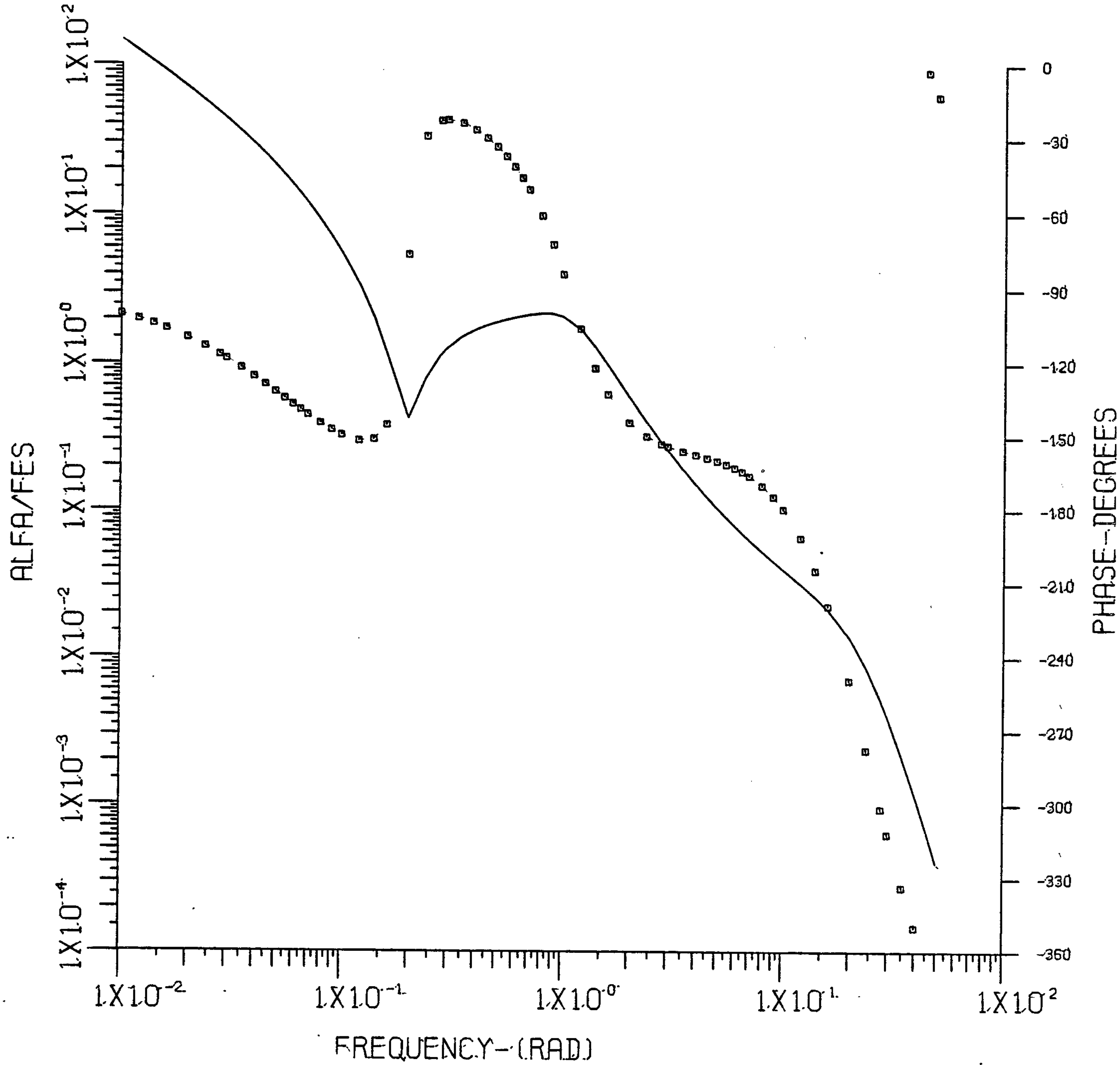
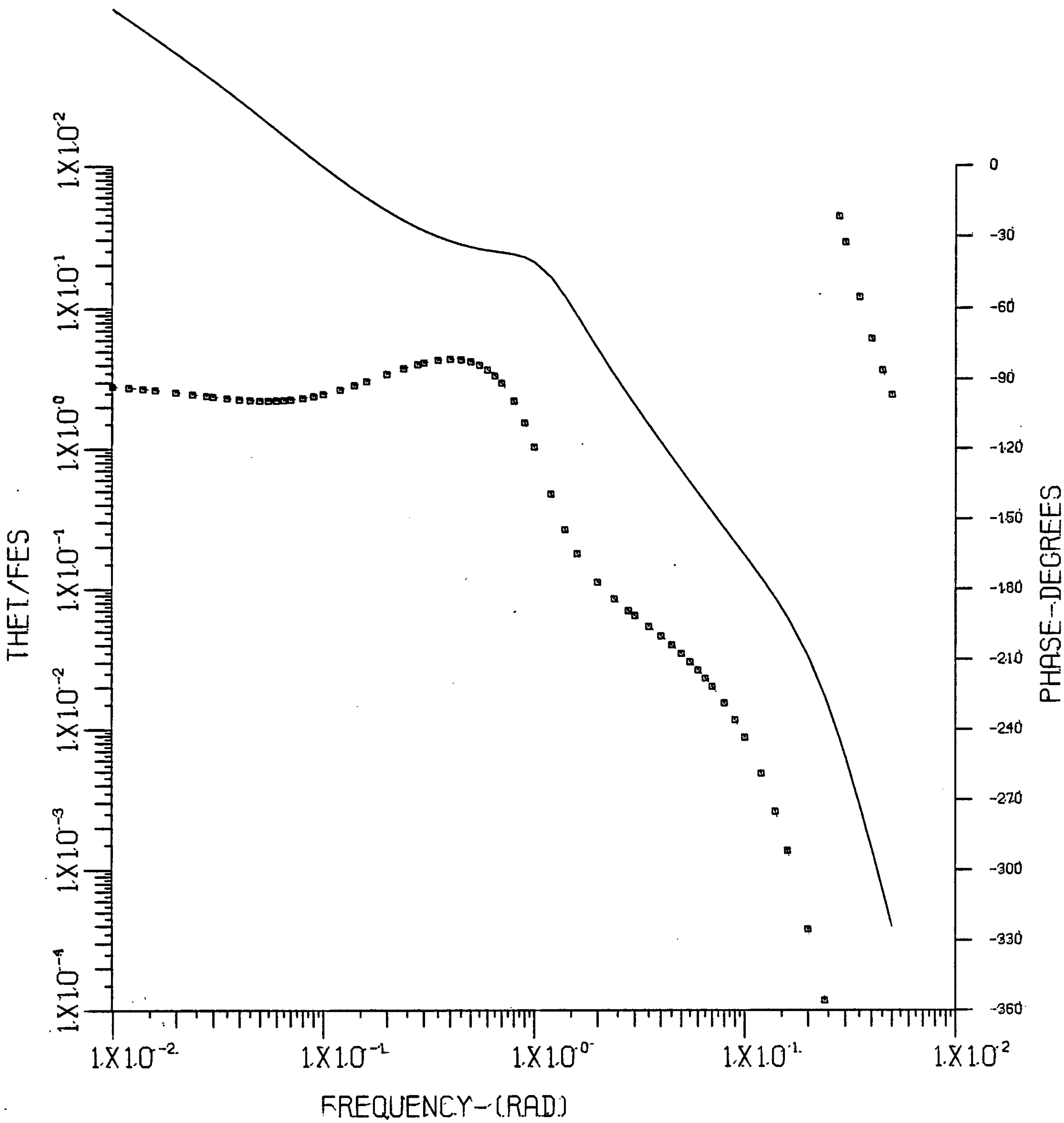


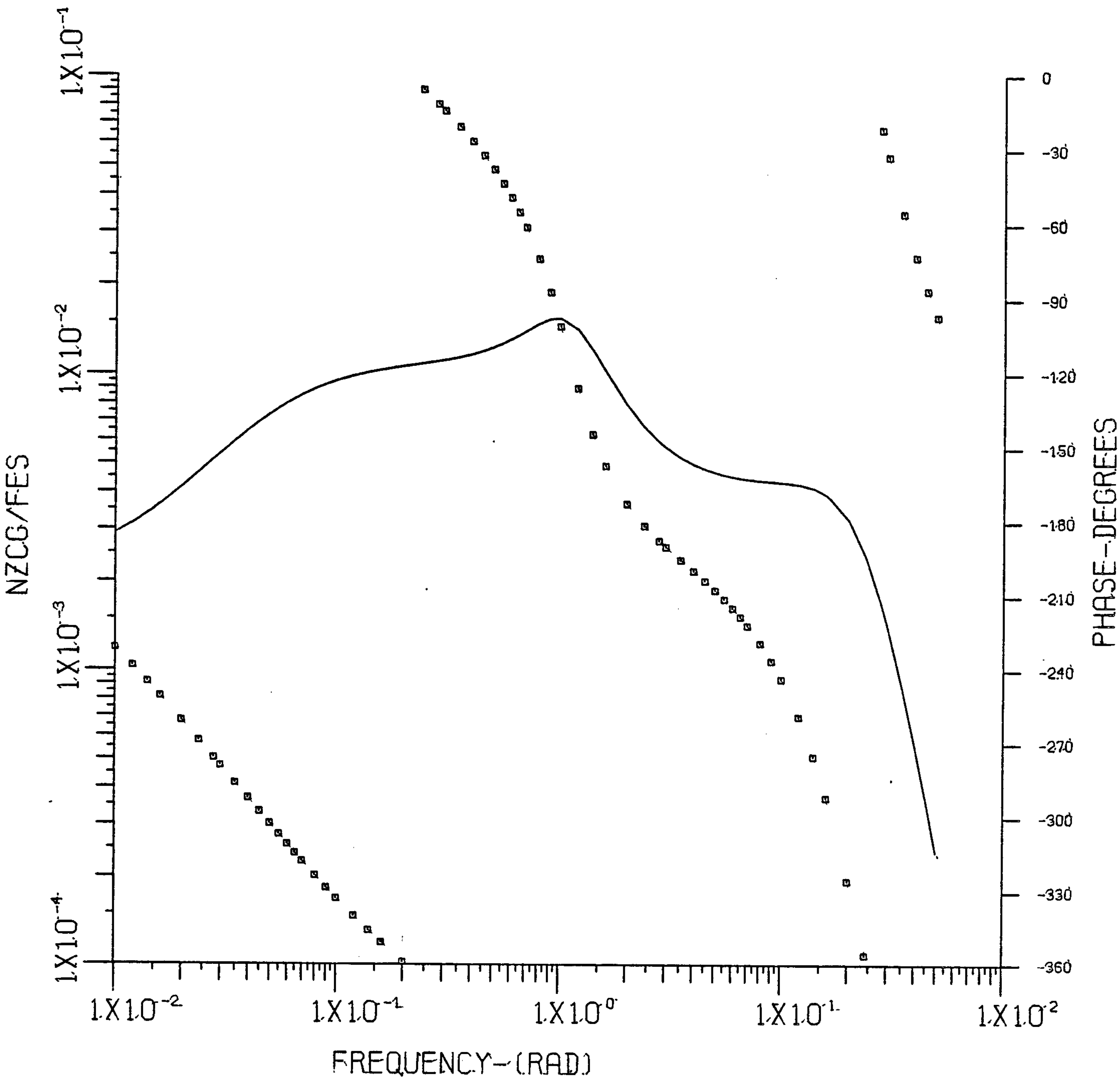
Configuration 8-2-5



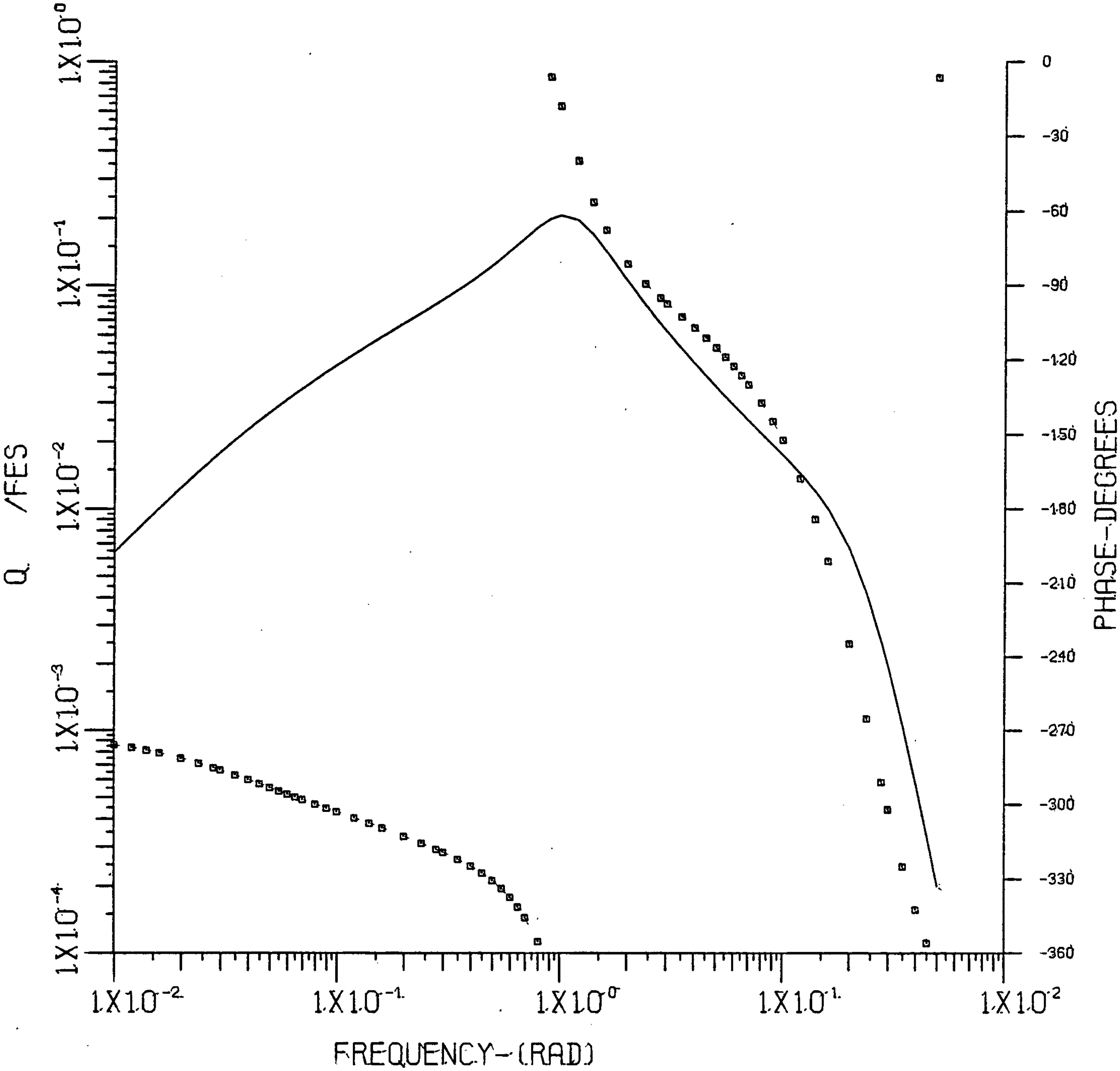
Configuration 8-2-5



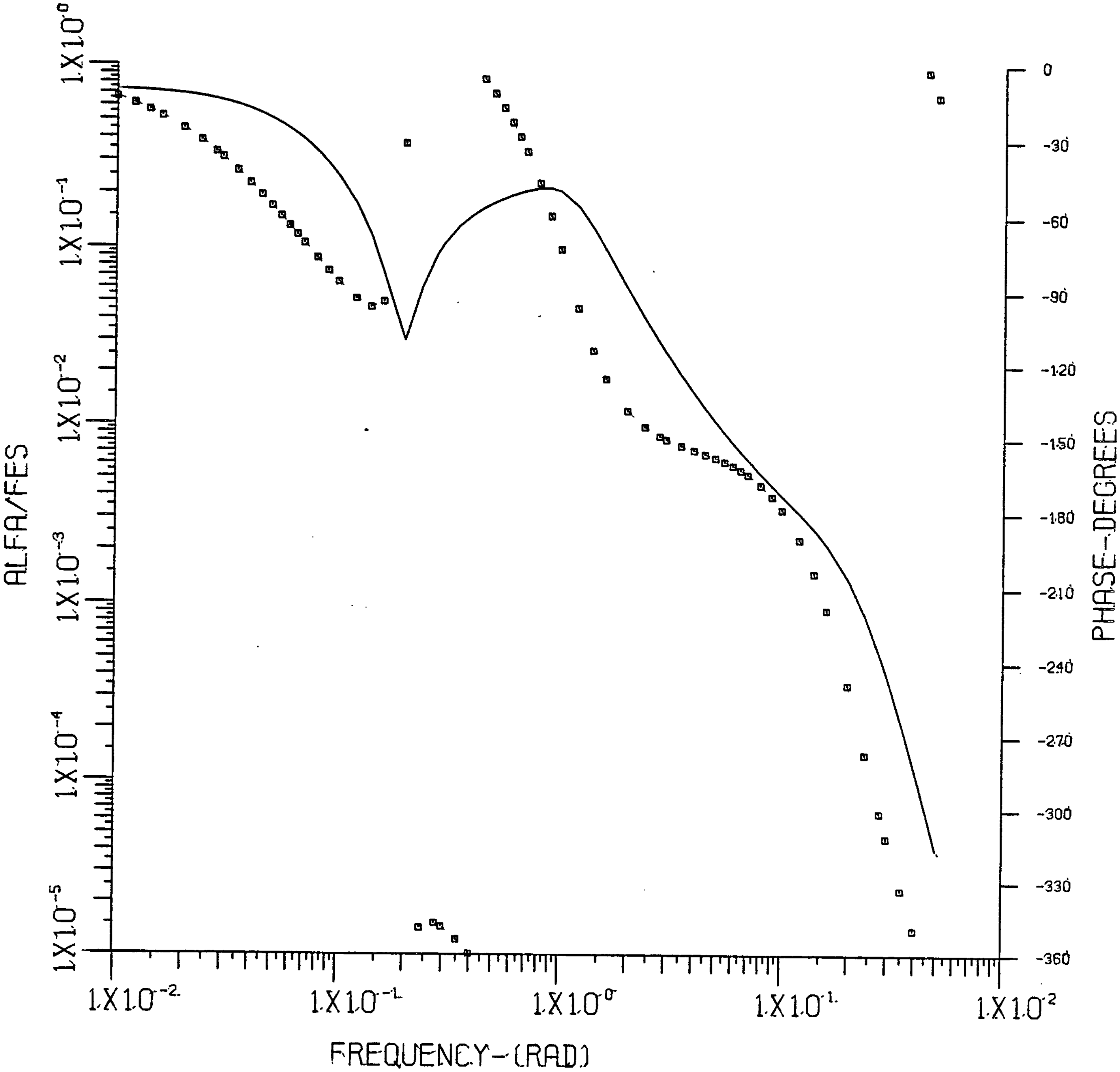
Configuration 8-2-5



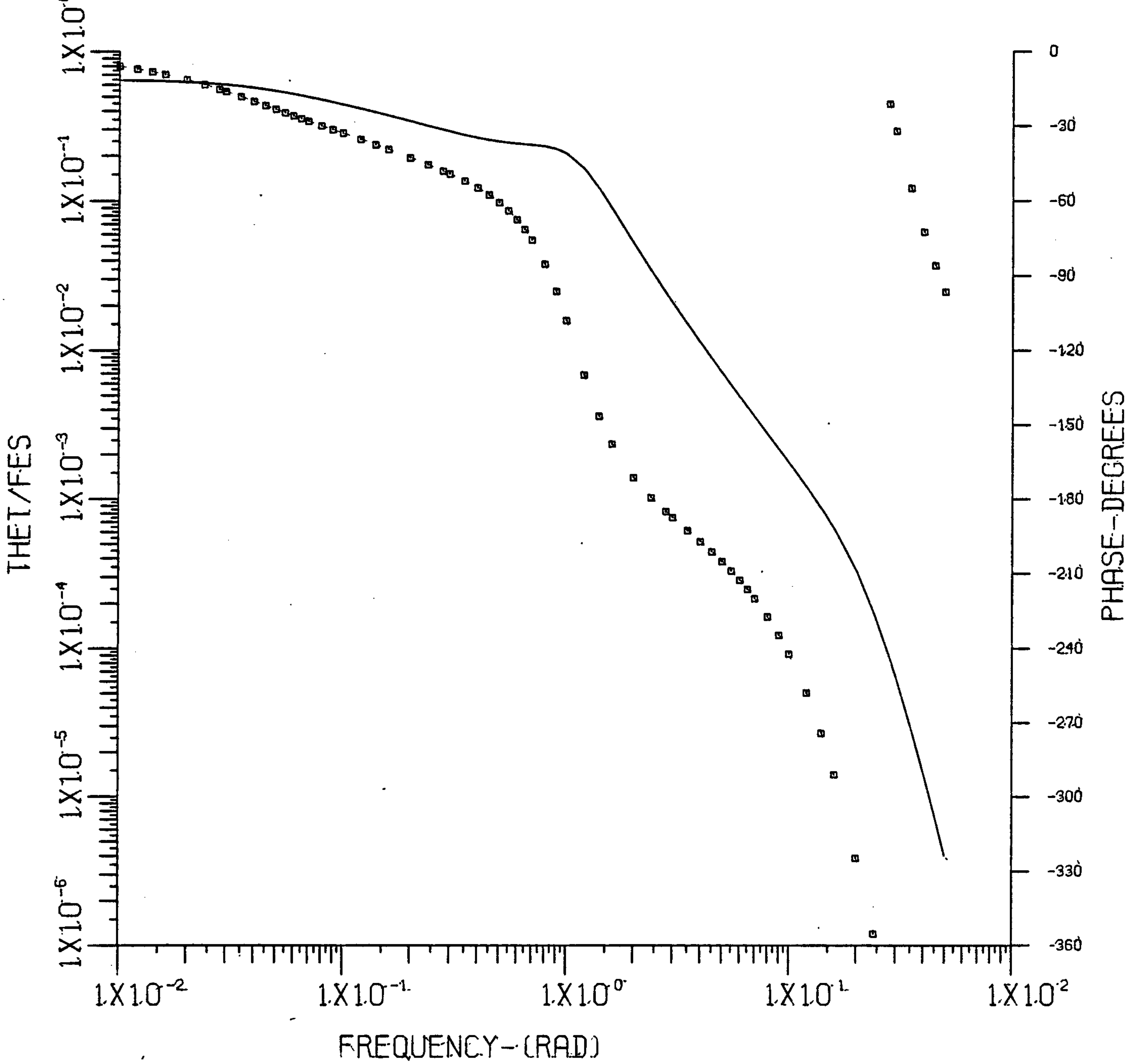
Configuration 8-2-5-1



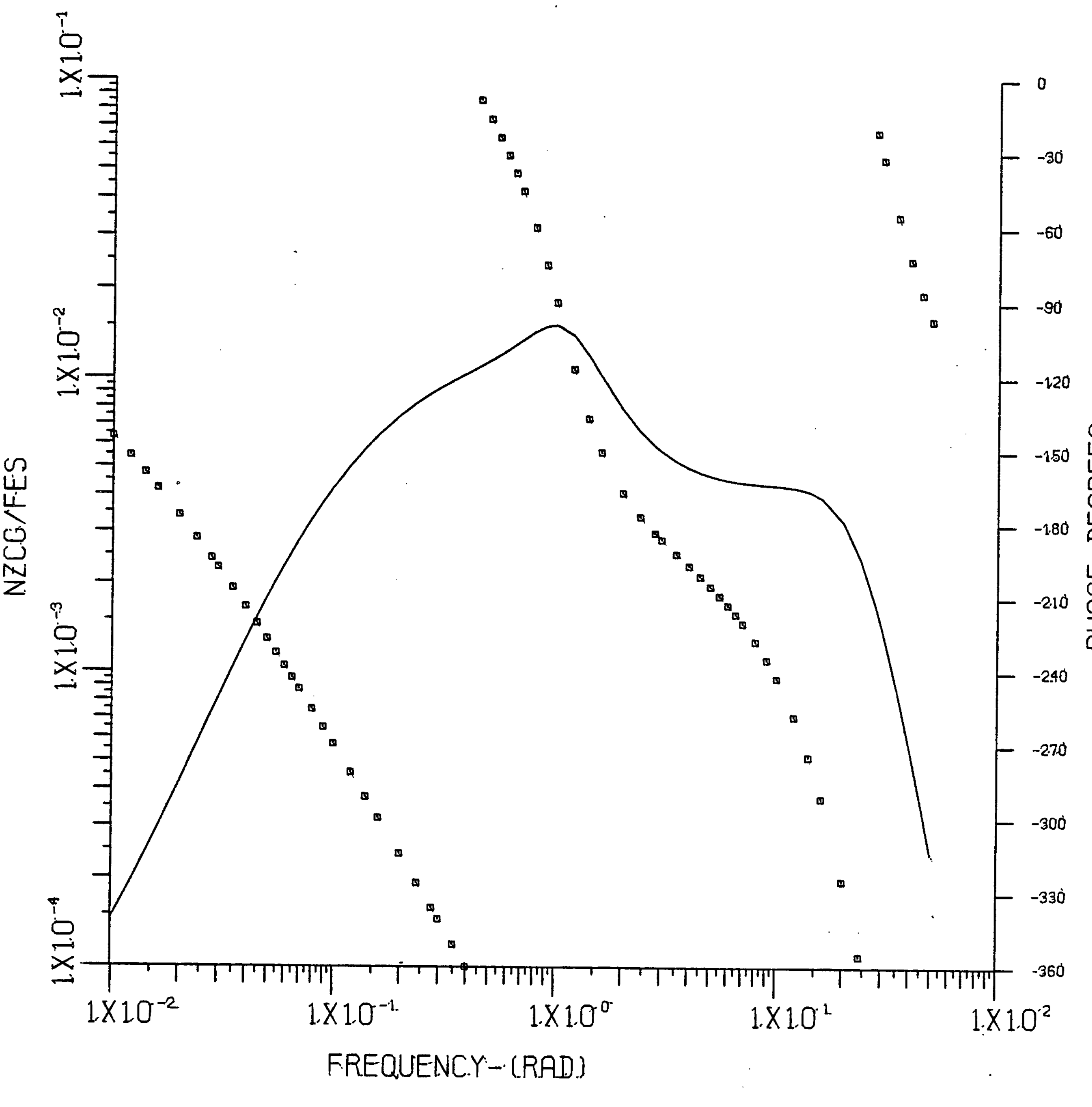
Configuration 8-2-5-1



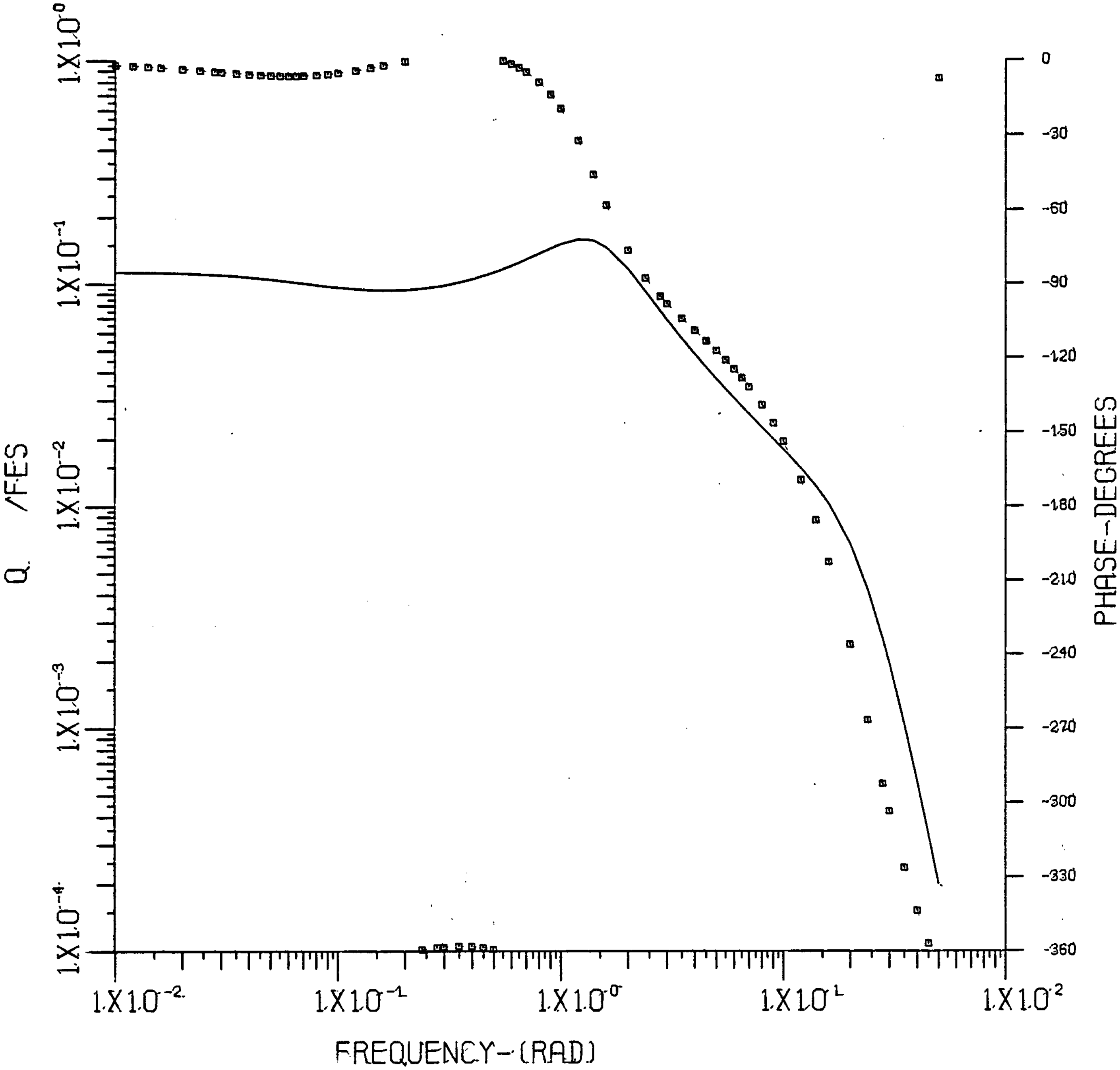
Configuration 8-2-5-1



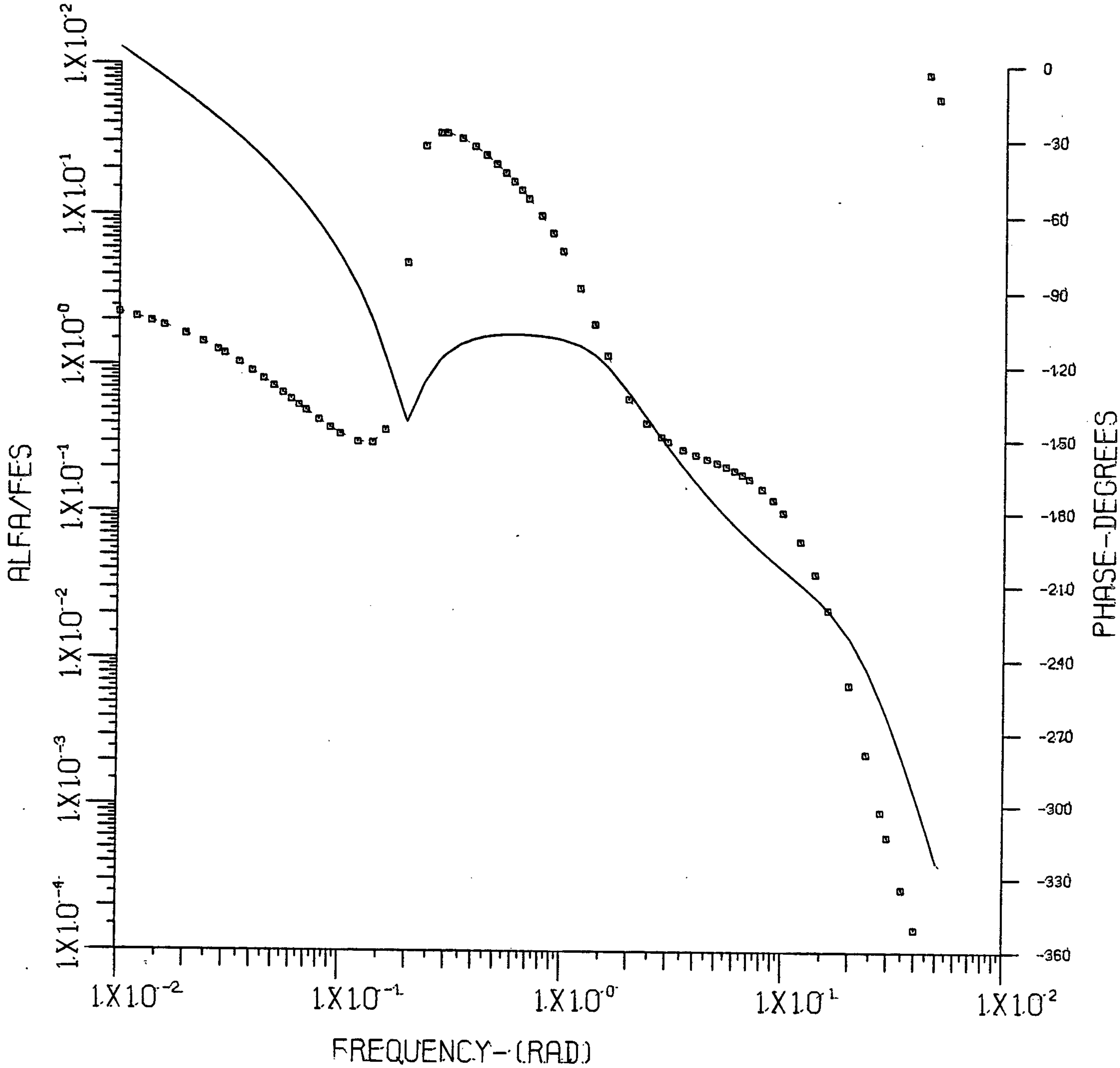
Configuration 8-2-5-1



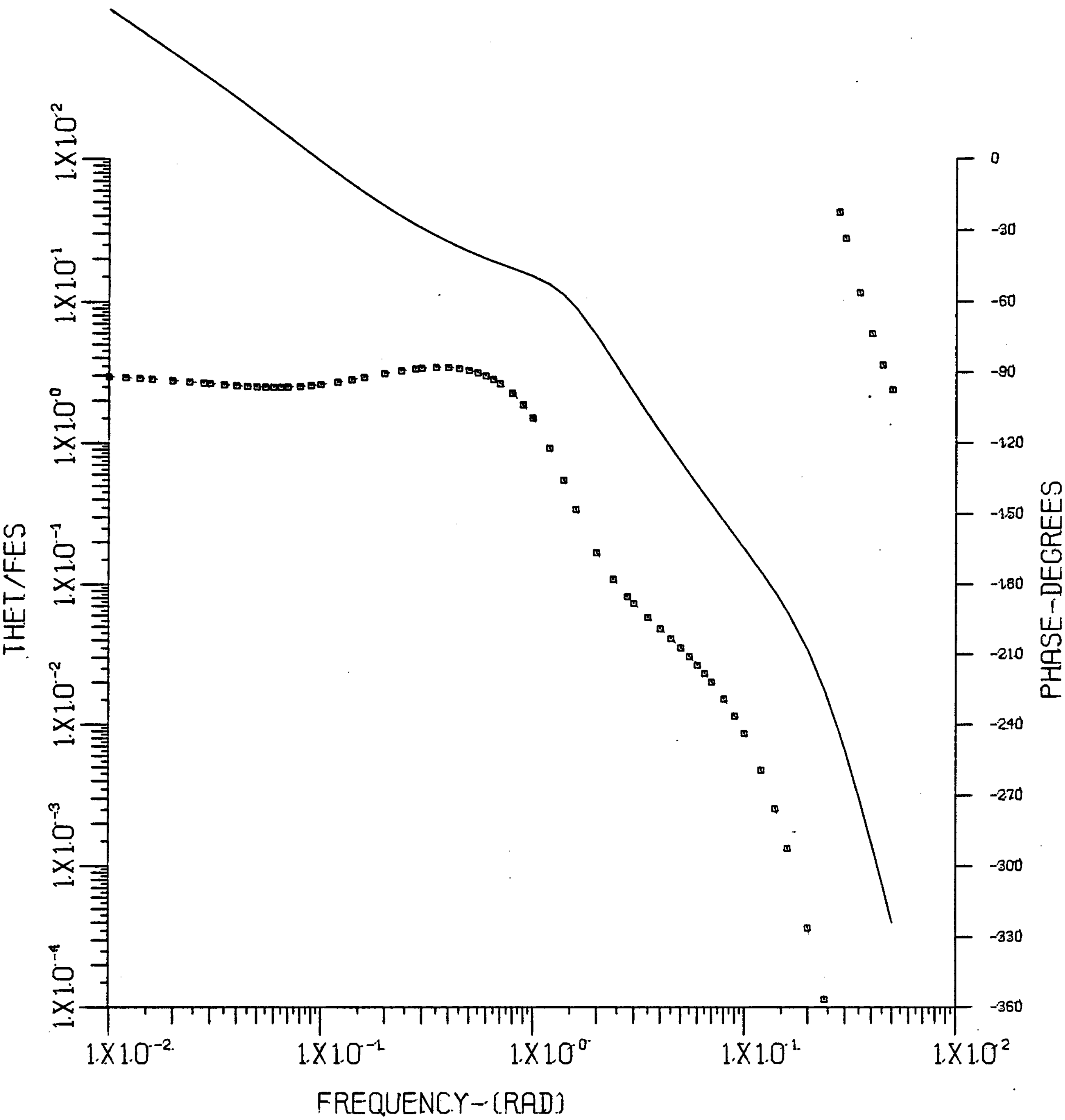
Configuration 8-3-5



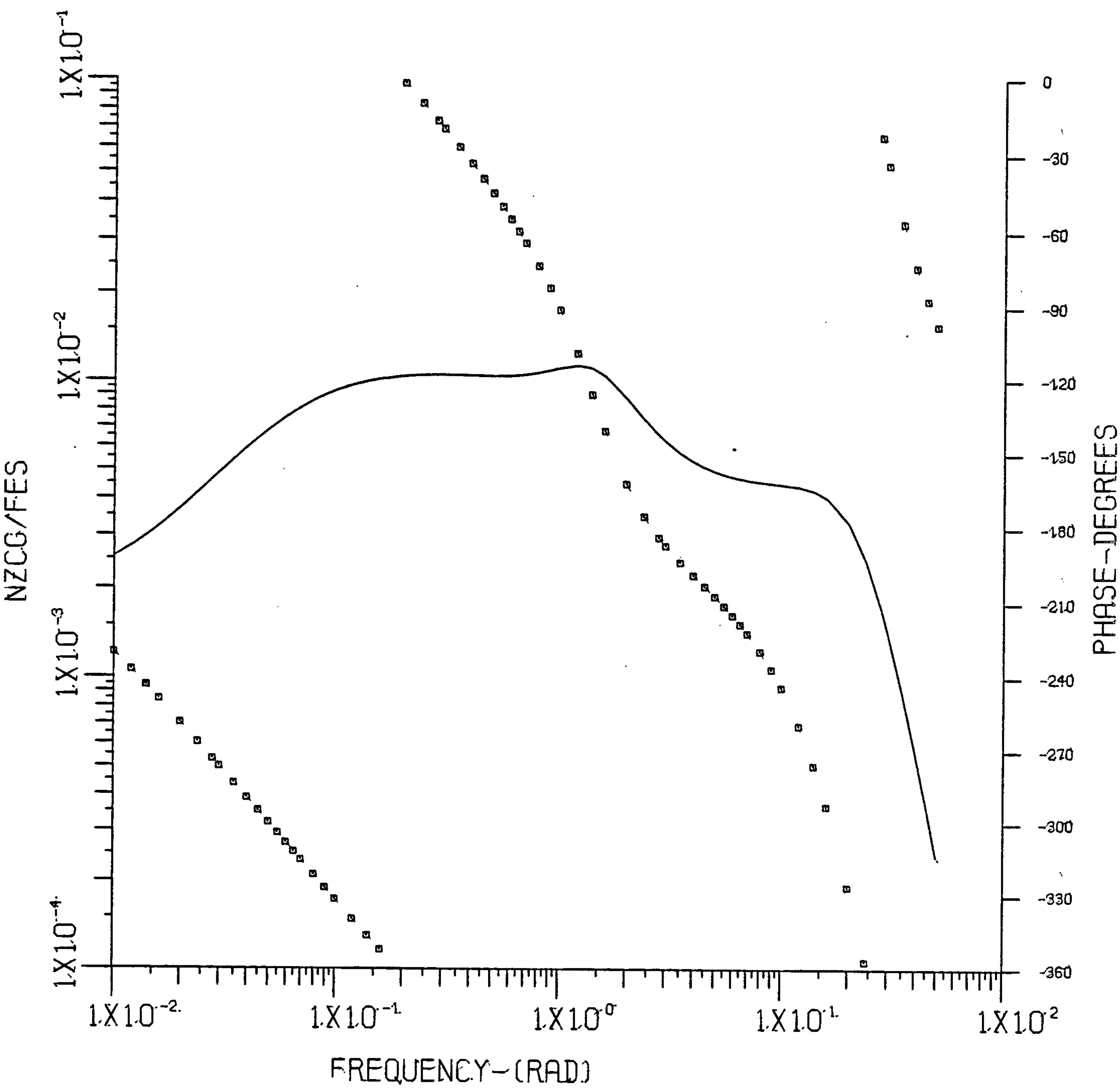
Configuration 8-3-5



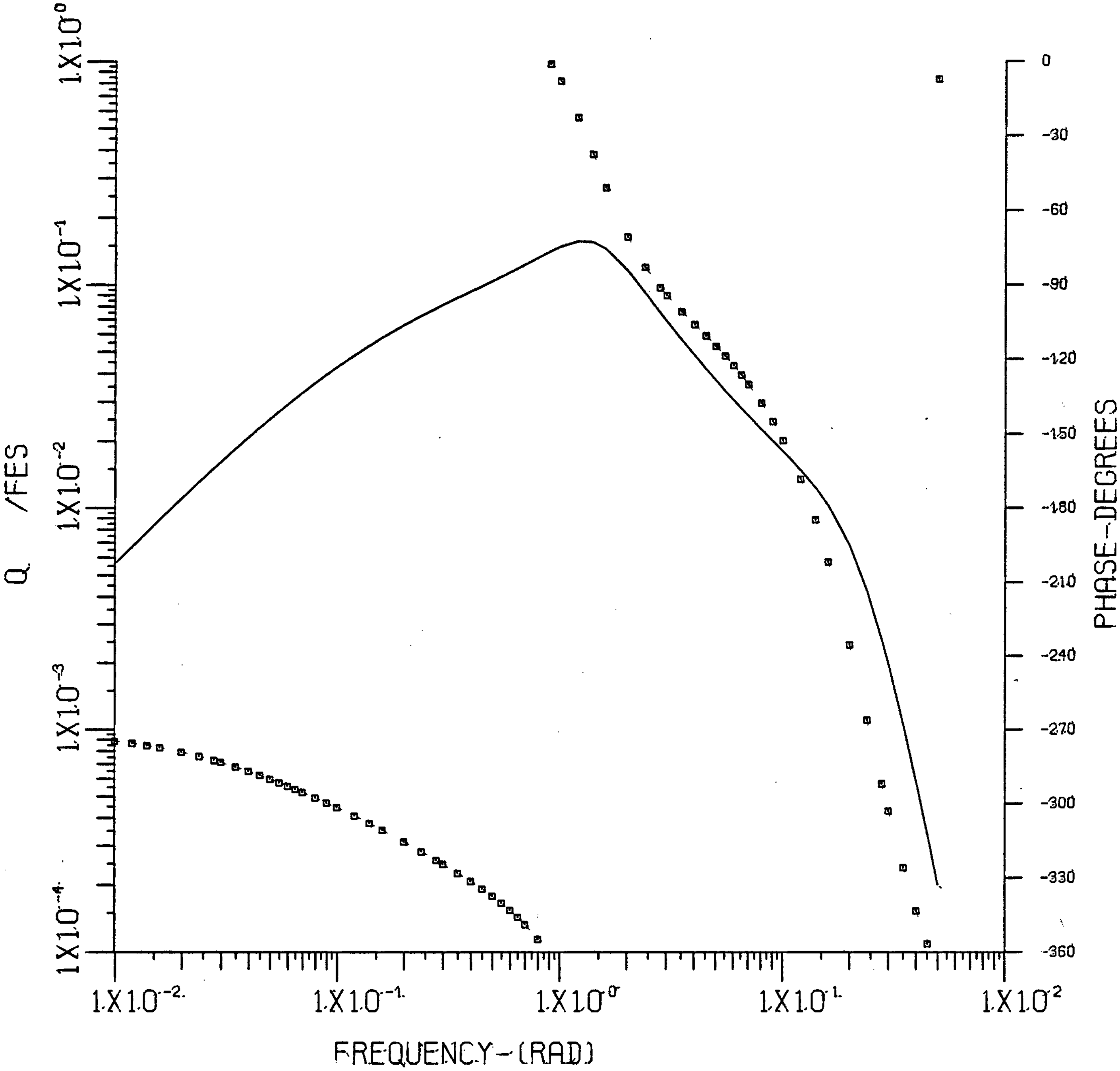
Configuration 8-3-5



Configuration 8-3-5



Configuration 8-3-5-1



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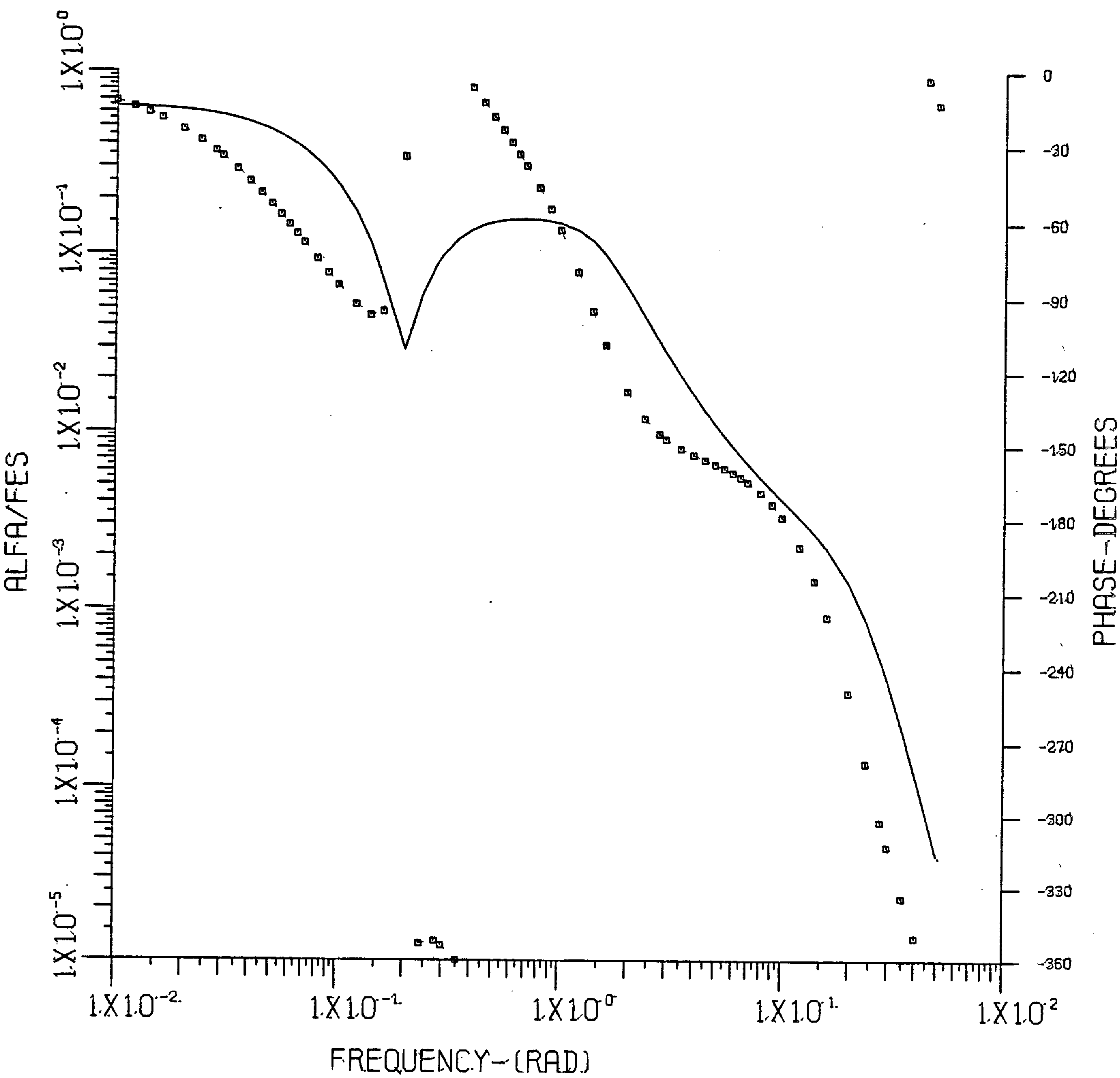

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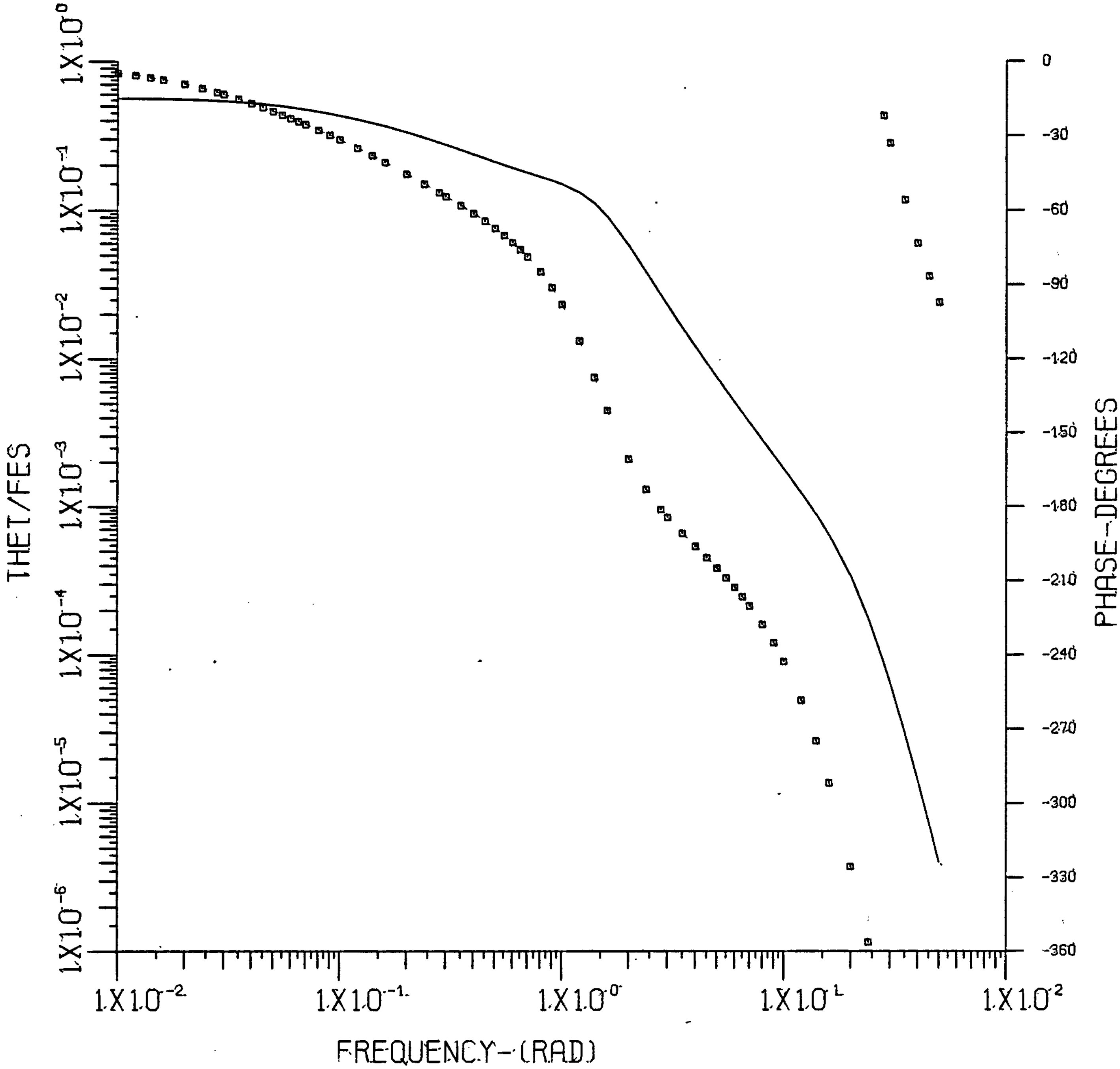

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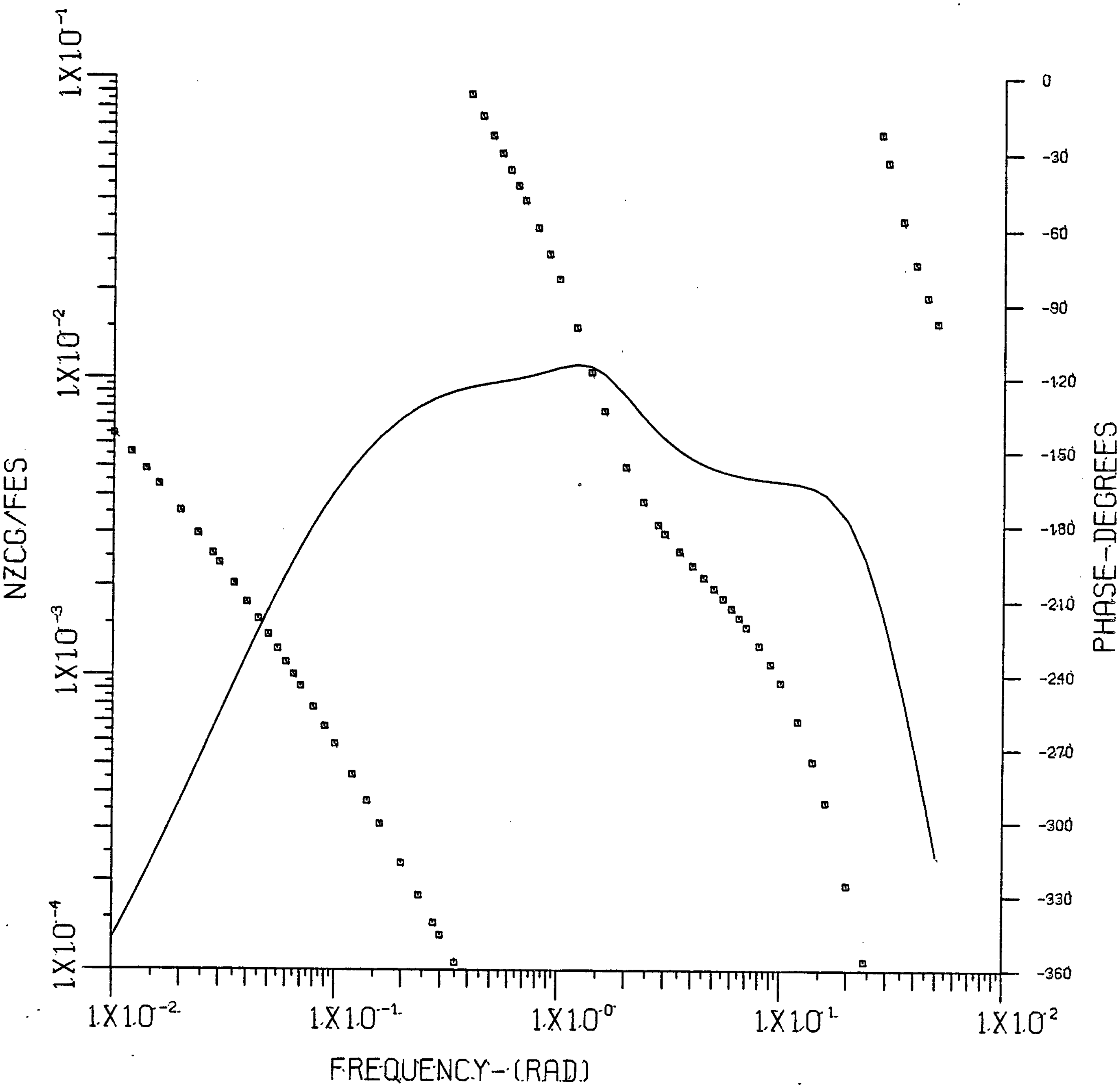
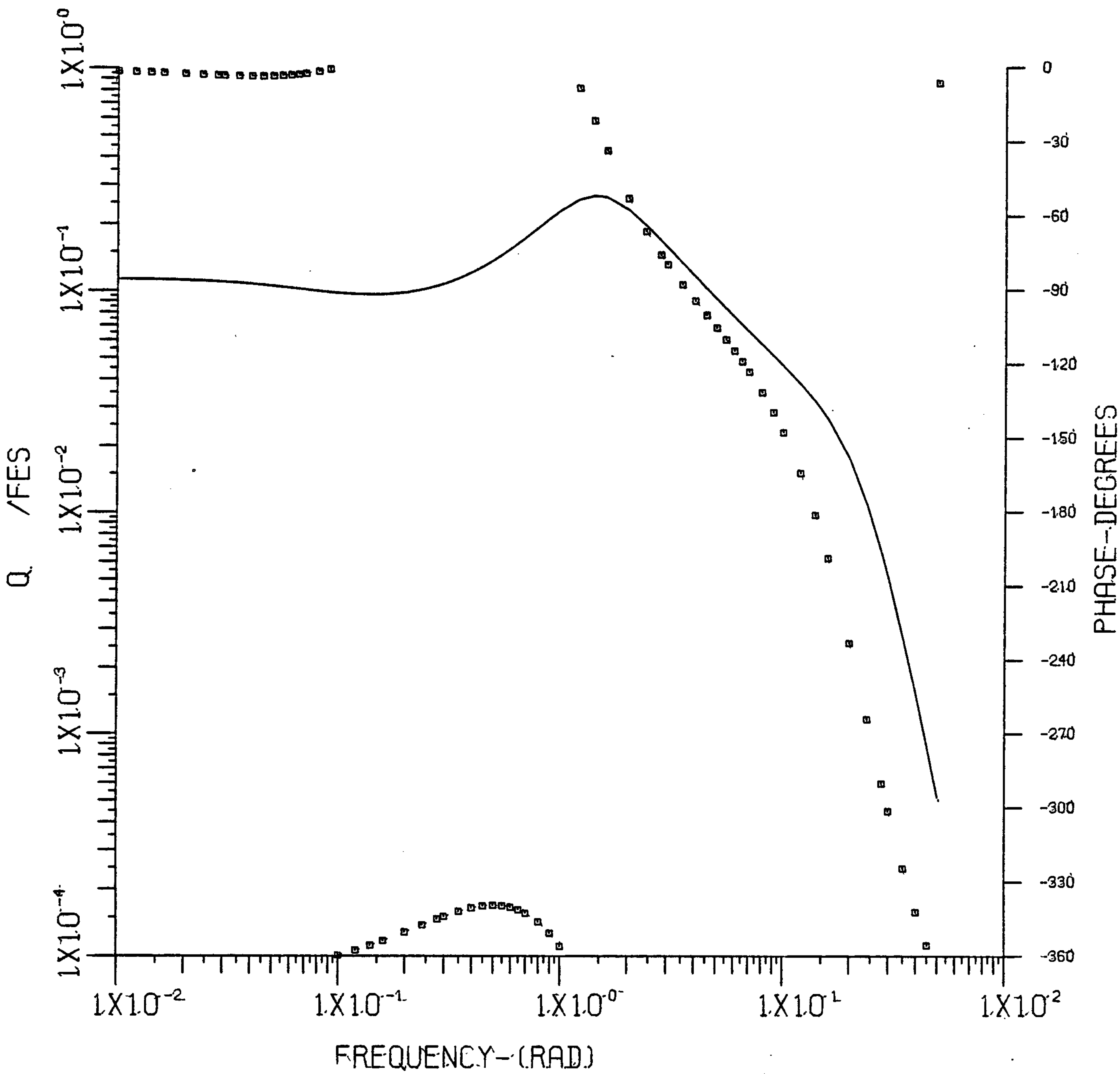
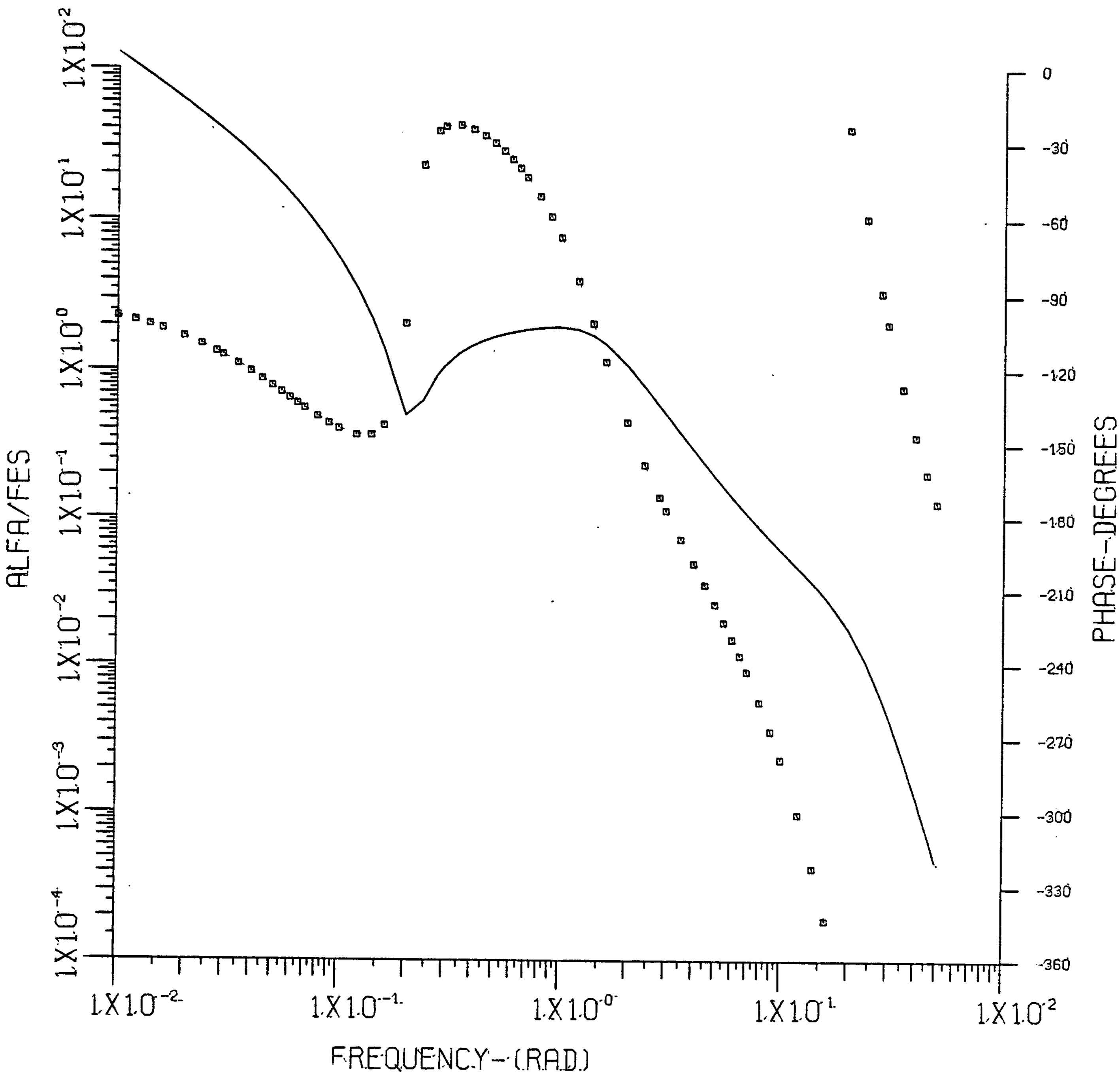


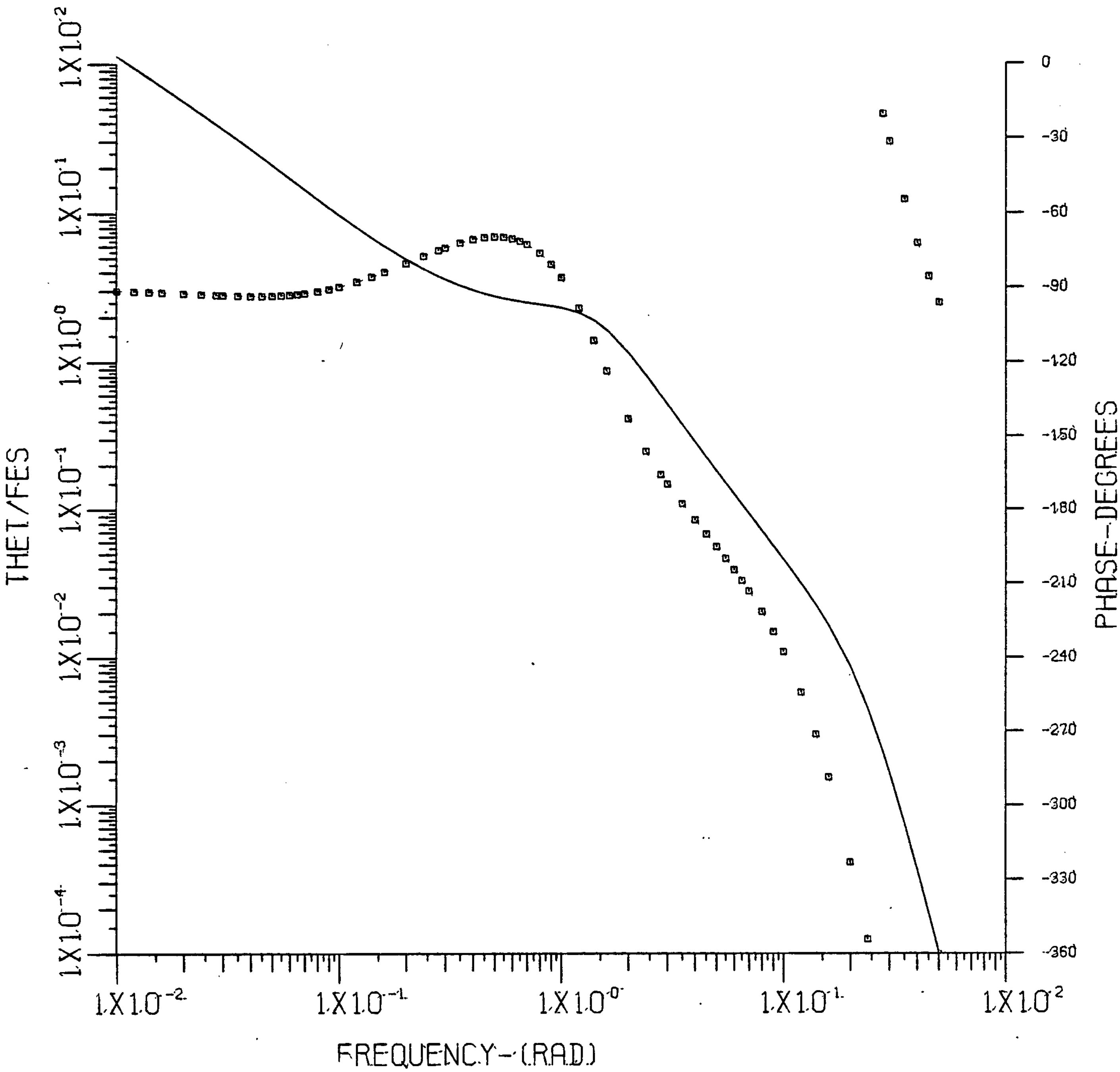
Configuration 8-4-6



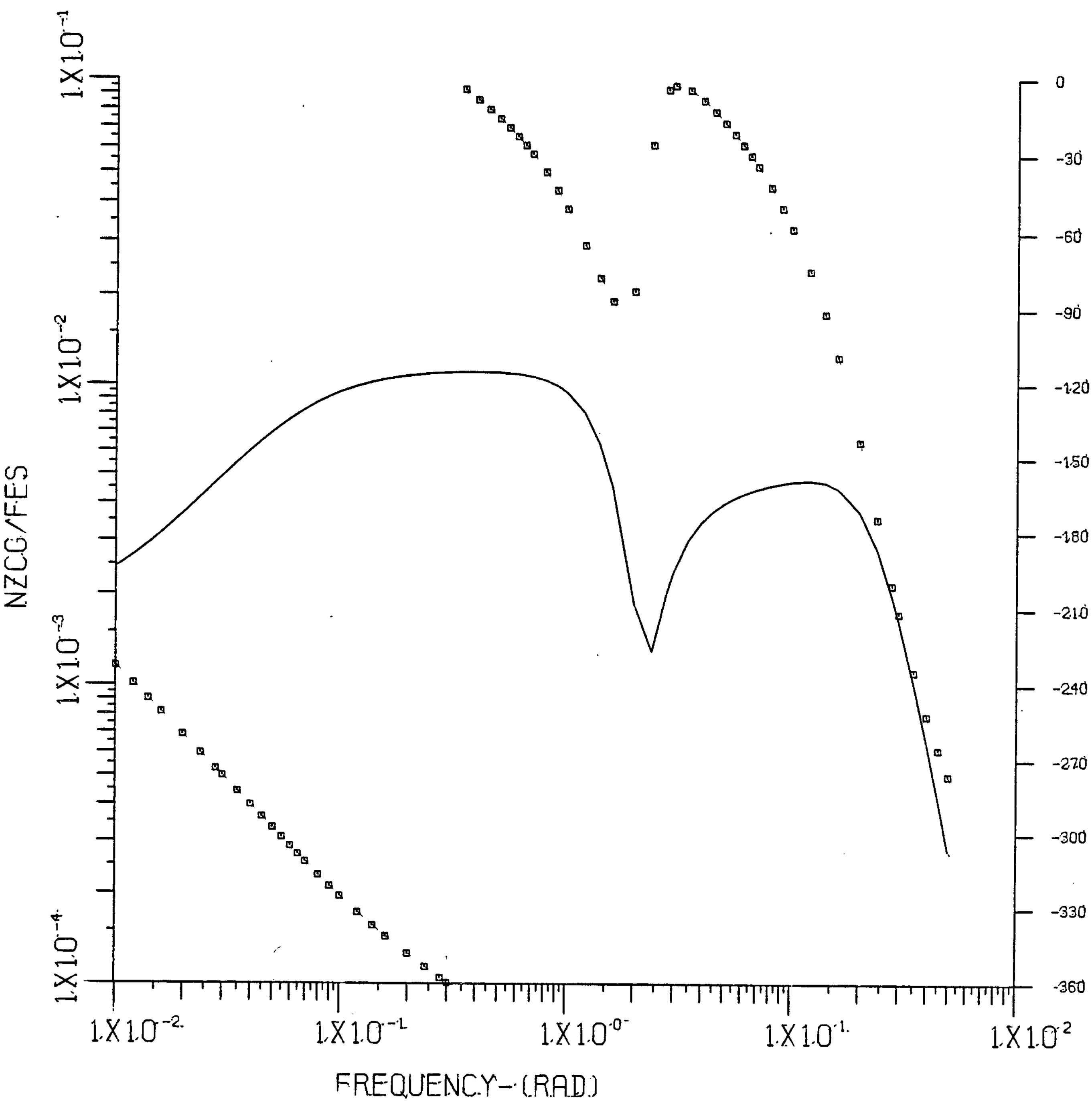
Configuration 8-4-6



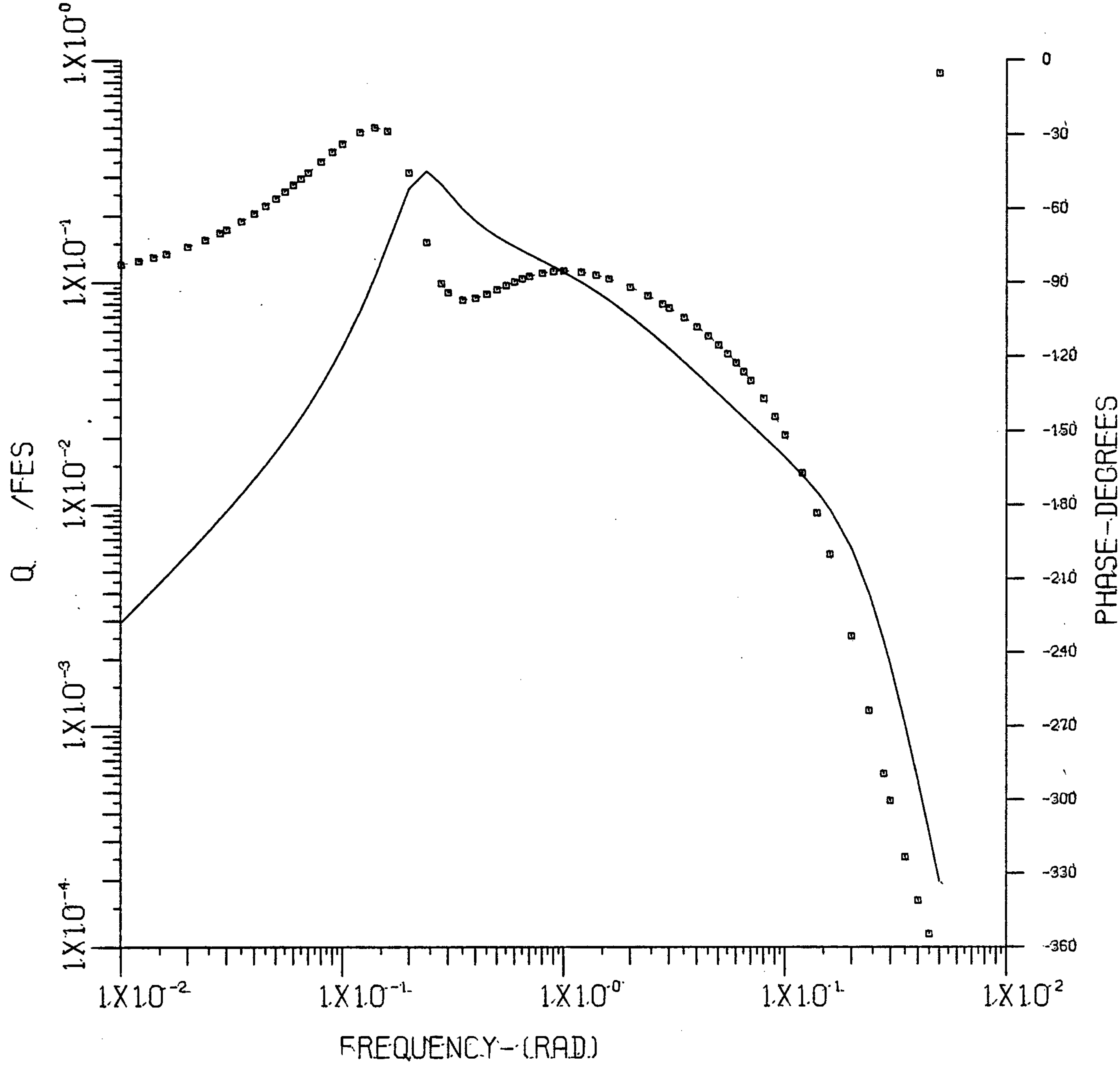
Configuration 8-4-6



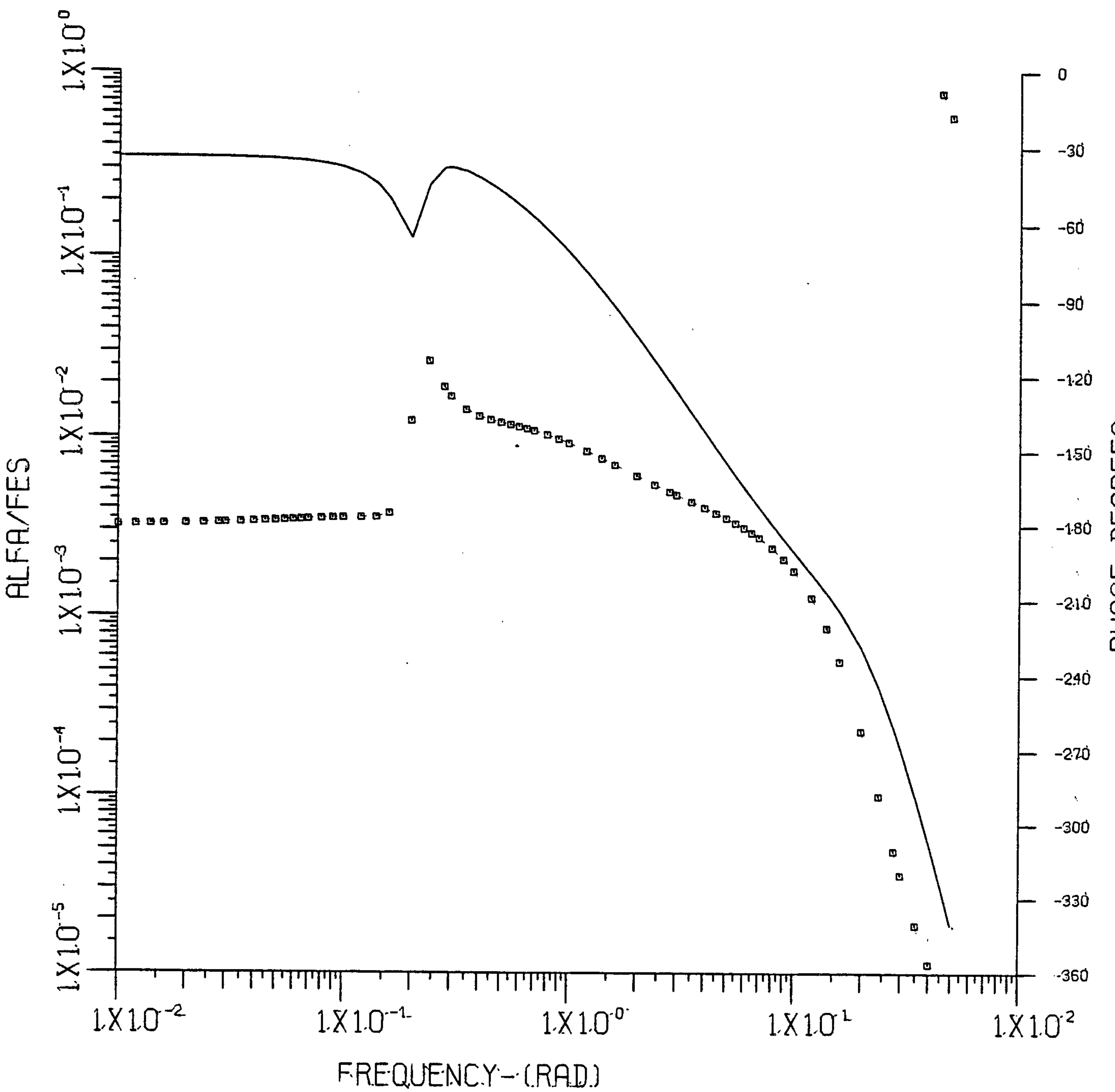
Configuration 8-4-6



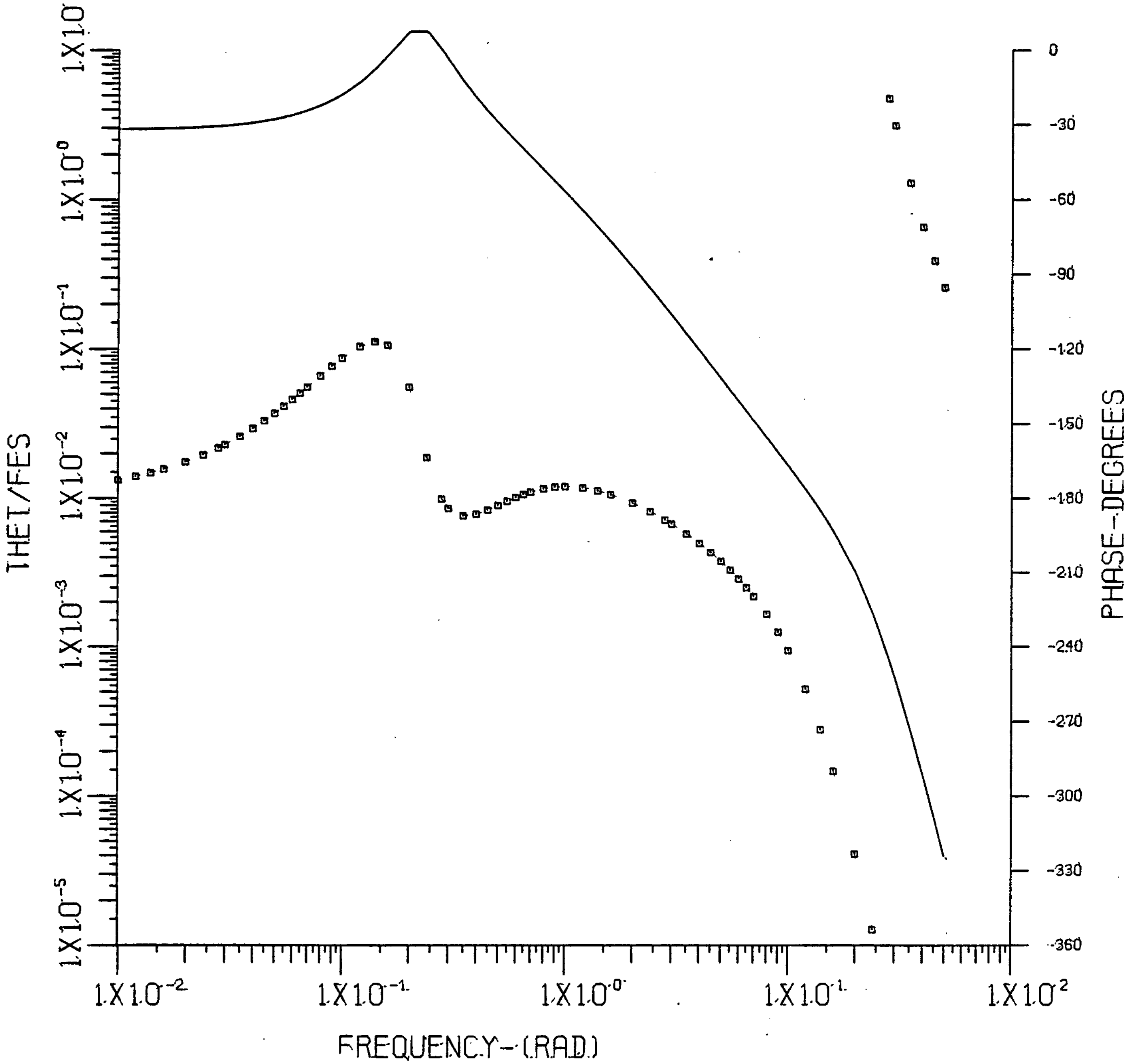
Configuration 10-1



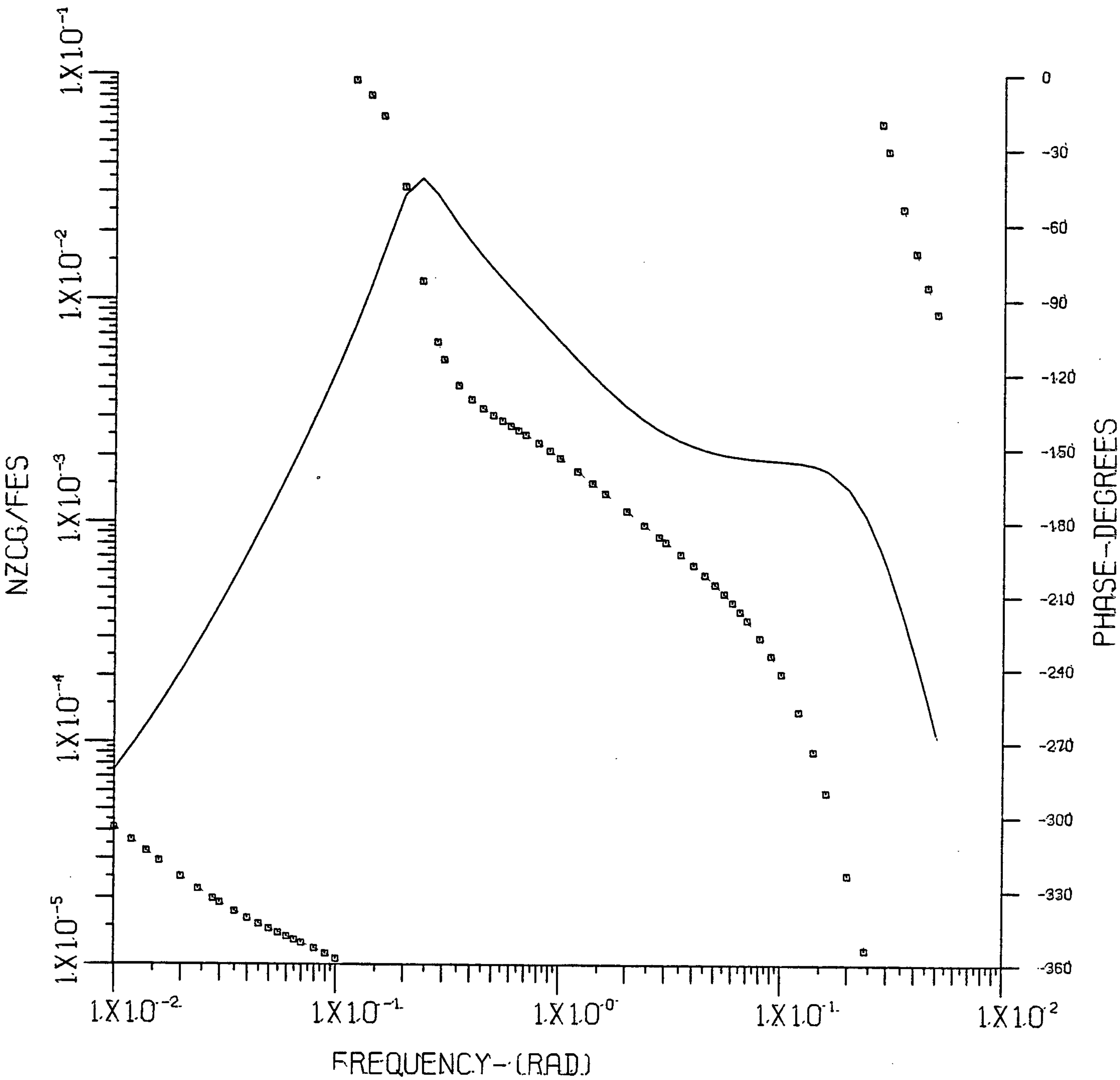
Configuration 10-1



Configuration 10-1



Configuration 10-1



APPENDIX C

TRANSFER FUNCTIONS

```
"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 1-1-1                                                    9 DEC 1983
                                                                                                 2:27 PM

******************** CH. EQ.  *****************
 1.00000D+00  6.83173D+01  2.47442D+03  4.70668D+04  5.31649D+05  2.06633D+06  3.85160D+06  2.07899D+06  3.69999D+05  1.85139D+04
 4.11092D-12  0.0
     REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -1.90260D+01   1.95206D+01  -3.80521D+01   7.43045D+02   6.97976D-01   2.72589D+01
  -8.31998D-02                                                                         1.20193D+01
  -4.34641D-01                                                                         2.30075D+00
  -2.17369D+00   1.75701D+00  -4.34738D+00   7.81200D+00   7.77707D-01   2.79499D+00
  -2.22045D-16                                                                         4.50360D+15
  -1.26000D+01   1.68000D+01  -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
  -2.00000D-01                                                                         5.00000D+00
   0.0                                                                                 0.0

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 2.30523D+04  3.15160D+05  6.03190D+05  1.43159D+05  2.81181D+04  4.22590D+03  0.0
     REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -1.14288D+01                                                                         8.74983D-02
  -2.00000D+00                                                                         5.00000D-01
  -2.13785D-02   1.99105D-01  -4.27571D-02   4.01000D-02   1.06759D-01   2.00250D-01
  -2.00000D-01                                                                         5.00000D+00
   0.0                                                                                 0.0

******************** Q    /FES *****************
 2.52129D+05  6.74273D+05  3.72936D+05  6.76093D+04  3.59519D+03 -1.23192D-08  0.0
     REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -2.00000D+00                                                                         5.00000D-01
  -3.80673D-01                                                                         2.62692D+00
  -2.00000D-01                                                                         5.00000D+00
  -9.36454D-02                                                                         1.06786D+01
   3.42657D-12                                                                        -2.91837D+11
   0.0                                                                                 0.0

******************** THET/FES *****************
 2.52129D+05  6.74273D+05  3.72936D+05  6.76093D+04  3.59519D+03  0.0
     REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -2.00000D+00                                                                         5.00000D-01
  -3.80673D-01                                                                         2.62692D+00
  -2.00000D-01                                                                         5.00000D+00
  -9.36454D-02                                                                         1.06786D+01
   0.0                                                                                 0.0

******************** NZCG/FES *****************
-2.78800D+03 -7.62317D+03  8.59700D+03  2.77898D+04  4.77617D+03 -7.62793D+01 -1.48991D-09  0.0
     REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

   1.89950D+00                                                                        -5.26453D-01
  -2.44849D+00                                                                         4.08415D-01
  -2.00000D+00                                                                         5.00000D-01
  -2.00000D-01                                                                         5.00000D+00
   1.47067D-02                                                                        -6.79961D+01
  -1.95323D-11                                                                         5.11973D+10
   0.0                                                                                 0.0
```

```
"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 1-2-2                                                              9 DEC 1983
                                                                                                         2:27 PM

******************** CH. EQ.  *****************
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 4.18760D-12  0.0
      REAL         IMAG          -2*Z*W          0**2          ZETA          OMEGA          TAU

  -1.90263D+01   1.95207D+01   -3.80526D+01   7.43057D+02   6.97980D-01   2.72591D+01
  -5.24673D-02
  -8.20825D-01                                                                          1.90595D+01
  -2.14755D+00   1.73908D+00   -4.29510D+00   7.63637D+00   7.77140D-01   2.76340D+00    1.21829D+00
  -1.94289D-16
  -1.26000D+01   1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01    5.14697D+15
  -2.00000D-01                                                                          5.00000D+00
   0.0                                                                                  0.0

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 2.30523D+04  3.15160D+05  6.03190D+05  1.43159D+05  2.81181D+04  4.22590D+03  0.0
      REAL         IMAG          -2*Z*W          0**2          ZETA          OMEGA          TAU

  -1.14288D+01                                                                          8.74983D-02
  -2.00000D+00                                                                          5.00000D-01
  -2.13735D-02   1.99105D-01   -4.27571D-02   4.01000D-02   1.06759D-01   2.00250D-01
  -2.00000D-01                                                                          5.00000D+00
   0.0                                                                                  0.0

******************** Q   /FES *****************
 2.52129D+05  7.51477D+05  5.44154D+05  1.01506D+05  4.14346D+03 -5.57094D-09  0.0
      REAL         IMAG          -2*Z*W          0**2          ZETA          OMEGA          TAU

  -2.00000D+00                                                                          5.00000D-01
  -7.23758D-01                                                                          1.38168D+00
  -2.00000D-01                                                                          5.00000D+00
  -5.67659D-02                                                                          1.76162D+01
   1.34451D-12                                                                         -7.43764D+11
   0.0                                                                                  0.0

******************** THET/FES *****************
 2.52129D+05  7.51477D+05  5.44154D+05  1.01506D+05  4.14346D+03  0.0
      REAL         IMAG          -2*Z*W          0**2          ZETA          OMEGA          TAU

  -2.00000D+00                                                                          5.00000D-01
  -7.23758D-01                                                                          1.38168D+00
  -2.00000D-01                                                                          5.00000D+00
  -5.67659D-02                                                                          1.76162D+01
   0.0                                                                                  0.0

******************** NZCG/FES *****************
-2.78800D+03 -7.62317D+03  1.79341D+04  4.84973D+04  8.87573D+03 -9.96946D+00 -6.73763D-10  0.0
      REAL         IMAG          -2*Z*W          0**2          ZETA          OMEGA          TAU

   2.57468D+00                                                                         -3.88398D-01
  -3.11007D+00                                                                          3.21536D-01
  -2.00000D+00                                                                          5.00000D-01
  -2.00000D-01                                                                          5.00000D+00
   1.11641D-03                                                                         -8.95725D+02
  -6.75827D-11                                                                          1.47967D+10
   0.0                                                                                  0.0
```

```
******************** CH. EQ.  *****************
[redacted]00000D+00  6.89053D+01  2.51428D+03  4.85015D+04  5.58621D+05  2.36624D+06  4.93396D+06  3.95779D+06  7.15792D+05  2.07083D+04
[redacted]
      REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

  -1.90266D+01    1.95207D+01   -3.80531D+01   7.43068D+02   6.97985D-01   2.72593D+01
  -2.11303D+00    1.72626D+00   -4.22606D+00   7.44485D+00   7.74422D-01   2.72853D+00
  -3.56514D-02                                                                            2.80494D+01
  -1.19046D+00                                                                            8.40010D-01
  -1.66533D-16                                                                            6.00480D+15
  -1.26000D+01    1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
[redacted]                                                                                5.00000D+00
   0.0                                                                                    0.0

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
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      REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

  -1.14288D+01                                                                            8.74983D-02
  -2.00000D+00                                                                            5.00000D-01
  -2.13785D-02    1.99105D-01   -4.27571D-02   4.01000D-02   1.06759D-01   2.00250D-01
  -2.00000D-01                                                                            5.00000D+00
   0.0                                                                                    0.0

******************** Q    /FES *****************
 2.52129D+05  8.23768D+05  7.02825D+05  1.29609D+05  3.99550D+03 -2.98398D-07  0.0
      REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

  -2.00000D+00                                                                            5.00000D-01
  -1.02874D+00                                                                            9.72067D-01
  -2.00000D-01                                                                            5.00000D+00
  -3.85109D-02                                                                            2.59667D+01
   7.46837D-11                                                                           -1.33898D+10
   0.0                                                                                    0.0

******************** THET/FES *****************
 2.52129D+05  8.23768D+05  7.02825D+05  1.29609D+05  3.99550D+03  0.0
      REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

  -2.00000D+00                                                                            5.00000D-01
  -1.02874D+00                                                                            9.72067D-01
  -2.00000D-01                                                                            5.00000D+00
  -3.85109D-02                                                                            2.59667D+01
   0.0                                                                                    0.0

******************** NZCG/FES *****************
-2.78800D+03 -7.62317D+03  2.66772D+04  6.76873D+04  1.22745D+04 -2.78651D+01 [redacted]
     s7           s6            s5           s4           s3           s2           s          1
      REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

   3.08058D+00                                                                           -3.24614D-01
  -3.61711D+00                                                                            2.76464D-01
  -2.00000D+00                                                                            5.00000D-01
[redacted]                                                                                5.00000D+00
   2.24241D-03                                                                           -4.45950D+02
  -1.29513D-09                                                                            7.72122D+08
   0.0                                                                                    0.0
```

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"#C3FREQ2"(12/9/83)-PITCH RATE CONFIG 2-1-1                                                          9 DEC 1983
                                                                                                      2:27 PM

******************** CH. EQ. *****************
 1.00000D+00  6.83173D+01  2.47442D+03  4.54726D+04  4.87211D+05  1.25346D+06  1.91151D+06  1.02825D+06  1.80895D+05  8.48867D+03
 1.29584D-12  0.0

    REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

 -2.01075D+01   2.05153D+01   -4.02150D+01   8.25190D+02   6.99973D-01   2.87261D+01
 -7.39147D-02                                                                            1.35291D+01
 -4.99724D-01                                                                            2.00110D+00
 -1.06430D+00   1.42297D+00   -2.12860D+00   3.15759D+00   5.98944D-01   1.77696D+00
 -1.52656D-16                                                                            6.55069D+15
 -1.26000D+01   1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
 -2.00000D-01                                                                            5.00000D+00
  0.0                                                                                    0.0

                              NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 1.15261D+04  1.57580D+05  3.01595D+05  7.15795D+04  1.40590D+04  2.11295D+03  0.0

    REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

 -1.14288D+01                                                                            8.74983D-02
 -2.00000D+00                                                                            5.00000D-01
 -2.13785D-02   1.99105D-01   -4.27571D-02   4.01000D-02   1.06759D-01   2.00250D-01
 -2.00000D-01                                                                            5.00000D+00
  0.0                                                                                    0.0

******************** Q   /FES *****************
 1.26065D+05  3.37137D+05  1.86468D+05  3.38047D+04  1.79759D+03  1.49165D-09  0.0

    REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

 -2.00000D+00                                                                            5.00000D-01
 -3.80673D-01                                                                            2.62692D+00
 -2.00000D-01                                                                            5.00000D+00
 -9.36454D-02                                                                            1.06786D+01
 -8.29802D-13                                                                            1.20511D+12
  0.0                                                                                    0.0

******************** THET/FES *****************
 1.26065D+05  3.37137D+05  1.86468D+05  3.38047D+04  1.79759D+03  0.0

    REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

 -2.00000D+00                                                                            5.00000D-01
 -3.80673D-01                                                                            2.62692D+00
 -2.00000D-01                                                                            5.00000D+00
 -9.36454D-02                                                                            1.06786D+01
  0.0                                                                                    0.0

******************** NZCG/FES *****************
-1.39400D+03 -3.81158D+03  4.29850D+03  1.38949D+04  2.38808D+03 -3.81397D+01  1.80403D-10  0.0

    REAL           IMAG          -2*Z*W          O**2          ZETA          OMEGA          TAU

  1.89950D+00                                                                           -5.26453D-01
 -2.44849D+00                                                                            4.08415D-01
 -2.00000D+00                                                                            5.00000D-01
 -2.00000D-01                                                                            5.00000D+00
  1.47067D-02                                                                           -6.79961D+01
  4.73007D-12                                                                           -2.11413D+11
  0.0                                                                                    0.0
```

```
"NCBFREQ2"(12/9/83)-PITCH RATE CONFIG 2-2-2                                                    9 DEC 1983
                                                                                               2:27 PM

******************** CH. EQ. *****************
 1.00000D+00  6.86210D+01  2.49501D+03  4.62138D+04  5.00662D+05  1.39515D+06  2.22961D+06  1.52191D+06  2.75569D+05  9.99929D+03
 1.11014D-12  0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

   -2.01076D+01  2.05153D+01  -4.02153D+01  8.25195D+02  6.99975D-01  2.87262D+01
   -4.82721D-02                                                                     2.07159D+01
   -9.30914D-01                                                                     1.07421D+00
   -1.01327D+00  1.42499D+00  -2.02654D+00  3.05730D+00  5.79503D-01  1.74851D+00
   -1.11022D-16                                                                     9.00720D+15
   -1.26000D+01  1.68000D+01  -2.52000D+01  4.41000D+02  6.00000D-01  2.10000D+01
   -2.00000D-01                                                                     5.00000D+00
    0.0                                                                             0.0

                     NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 1.15261D+04  1.57580D+05  3.01595D+05  7.15795D+04  1.40590D+04  2.11295D+03  0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

   -1.14288D+01                                                                     8.74983D-02
   -2.00000D+00                                                                     5.00000D-01
   -2.13785D-02  1.99105D-01  -4.27571D-02  4.01000D-02  1.06759D-01  2.00250D-01
   -2.00000D-01                                                                     5.00000D+00
    0.0                                                                             0.0

******************** Q    /FES *****************
 1.26065D+05  3.75738D+05  2.72077D+05  5.07531D+04  2.07173D+03 -1.02649D-10  0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

   -2.00000D+00                                                                     5.00000D-01
   -7.23758D-01                                                                     1.38168D+00
   -2.00000D-01                                                                     5.00000D+00
   -5.67659D-02                                                                     1.76162D+01
    4.95473D-14                                                                    -2.01827D+13
    0.0                                                                             0.0

******************** THET/FES *****************
 1.26065D+05  3.75738D+05  2.72077D+05  5.07531D+04  2.07173D+03  0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

   -2.00000D+00                                                                     5.00000D-01
   -7.23758D-01                                                                     1.38168D+00
   -2.00000D-01                                                                     5.00000D+00
   -5.67659D-02                                                                     1.76162D+01
    0.0                                                                             0.0

******************** NZCG/FES *****************
-1.39400D+03 -3.81158D+03  8.96707D+03  2.42487D+04  4.43786D+03 -4.98473D+00 -1.24146D-11  0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

    2.57468D+00                                                                    -3.88398D-01
   -3.11007D+00                                                                     3.21536D-01
   -2.00000D+00                                                                     5.00000D-01
   -2.00000D-01                                                                     5.00000D+00
    1.11641D-03                                                                    -8.95725D+02
   -2.49052D-12                                                                     4.01522D+11
    0.0                                                                             0.0
```

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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 3-1-3                                                        13 DEC 1983
                                                                                                    2:17 PM

******************** CH. EQ.  ******************
 1.00000D+00  6.83839D+01  2.47940D+03  4.56665D+04  4.88028D+05  1.21956D+06  6.74925D+05  1.27745D+05  7.39587D+03 -2.92365D+01
 0.0          0.0

      REAL           IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -2.00064D+01    2.05231D+01   -4.00128D+01   8.21454D+02   6.98036D-01   2.86610D+01
  -2.49397D+00                                                                            4.00967D-01
  -3.59498D-01                                                                            2.78165D+00
  -1.21295D-01                                                                            8.24433D+00
   3.71058D-03                                                                           -2.69500D+02
  -2.00000D-01                                                                            5.00000D+00
  -1.26000D+01    1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
   0.0                                                                                    0.0
   0.0                                                                                    0.0

                    NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES ******************
 1.15261D+04  1.34528D+05  3.25391D+04  6.50129D+03  1.05647D+03  0.0          0.0
      REAL           IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -1.14288D+01                                                                            8.74983D-02
  -2.13785D-02    1.99105D-01   -4.27571D-02   4.01000D-02   1.06759D-01   2.00250D-01
  -2.00000D-01                                                                            5.00000D+00
   0.0                                                                                    0.0
   0.0                                                                                    0.0

******************** Q   /FES ******************
 1.26065D+05  8.82010D+04  1.79340D+04  1.06727D+03  0.0          0.0          0.0
      REAL           IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -3.91536D-01                                                                            2.55404D+00
  -2.00000D-01                                                                            5.00000D+00
  -1.08113D-01                                                                            9.24956D+00
   0.0                                                                                    0.0
   0.0                                                                                    0.0
   0.0                                                                                    0.0

******************** THET/FES ******************
 1.26065D+05  8.82010D+04  1.79340D+04  1.06727D+03  0.0          0.0
      REAL           IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -3.91536D-01                                                                            2.55404D+00
  -2.00000D-01                                                                            5.00000D+00
  -1.08113D-01                                                                            9.24956D+00
   0.0                                                                                    0.0
   0.0                                                                                    0.0

******************** NZCG/FES ******************
-1.39400D+03 -1.02359D+03  6.73188D+03  1.38270D+03  1.30560D+00  0.0          0.0          0.0
      REAL           IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -2.50445D+00                                                                            3.99290D-01
   1.97111D+00                                                                           -5.07327D-01
  -2.00000D-01                                                                            5.00000D+00
  -9.48624D-04                                                                            1.05416D+03
   0.0                                                                                    0.0
   0.0                                                                                    0.0
   0.0                                                                                    0.0
```

******************** CH. EQ. *****************

1.00000D+00 6.86496D+01 2.49741D+03 4.63144D+04 4.99776D+05 1.34230D+06 9.27666D+05 1.70505D+05 6.71541D+03 -4.64626D+01
0.0 0.0

REAL	IMAG	-2*Z*W	D**2	ZETA	OMEGA	TAU
-2.00065D+01	2.05231D+01	-4.00130D+01	8.21458D+02	6.98037D-01	2.86611D+01	
-2.50907D+00						3.98553D-01
-6.69670D-01						1.49327D+00
-6.38141D-02						1.56705D+01
5.98080D-03						-1.67202D+02
-2.00000D-01						5.00000D+00
-1.26000D+01	1.68000D+01	-2.52000D+01	4.41000D+02	6.00000D-01	2.10000D+01	
0.0						0.0
0.0						0.0

NUMERATORS OF TRANSFER FUNCTIONS./FES

******************** ALFA/FES *****************

1.15261D+04 1.34528D+05 3.25391D+04 6.50129D+03 1.05647D+03 0.0 0.0

REAL	IMAG	-2*Z*W	D**2	ZETA	OMEGA	TAU
-1.14298D+01						8.74983D-02
-2.13785D-02	1.99105D-01	-4.27571D-02	4.01000D-02	1.06759D-01	2.00250D-01	
-2.00000D-01						5.00000D+00
0.0						0.0
0.0						0.0

******************** Q /FES *****************

1.26065D+05 1.21977D+05 2.42729D+04 9.84009D+02 0.0 0.0 0.0

REAL	IMAG	-2*Z*W	D**2	ZETA	OMEGA	TAU
-7.12825D-01						1.40287D+00
-2.00000D-01						5.00000D+00
-5.47512D-02						1.82644D+01
0.0						0.0
0.0						0.0
0.0						0.0

******************** THET/FES *****************

1.26065D+05 1.21977D+05 2.42729D+04 9.84009D+02 0.0 0.0

REAL	IMAG	-2*Z*W	D**2	ZETA	OMEGA	TAU
-7.12825D-01						1.40287D+00
-2.00000D-01						5.00000D+00
-5.47512D-02						1.82644D+01
0.0						0.0
0.0						0.0

******************** NZCG/FES *****************

-1.39400D+03 -1.02359D+03 1.03168D+04 2.14934D+03 -8.76402D+00 0.0 0.0 0.0

REAL	IMAG	-2*Z*W	D**2	ZETA	OMEGA	TAU
-3.08635D+00						3.24007D-01
2.54808D+00						-3.92453D-01
-2.00000D-01						5.00000D+00
3.99717D-03						-2.50177D+02
0.0						0.0
0.0						0.0
0.0						0.0

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"#C3FREQ2"(12/9/83)-PITCH RATE CONFIG 4-1-1                                                          9 DEC 1983
                                                                                                      2:27 PM

******************** CH. EQ.  *****************
 1.00000D+00  7.03173D+01  2.61105D+03  5.20156D+04  6.25783D+05  3.12962D+06  7.98425D+06  9.78218D+06  4.52798D+06  7.58511D+05
 3.70279D+04  8.22184D-12

     REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA         TAU

 -1.90260D+01  1.95206D+01  -3.80521D+01  7.43045D+02  6.97976D-01  2.72589D+01
 -3.31998D-02
 -4.34641D-01                                                                          1.20193D+01
 -2.17369D+00  1.75701D+00  -4.34738D+00  7.81200D+00  7.77707D-01  2.79499D+00        2.30075D+00
 -2.22045D-16                                                                          4.50360D+15
 -1.26000D+01  1.68000D+01  -2.52000D+01  4.41000D+02  6.00000D-01  2.10000D+01
 -2.00000D+00                                                                          5.00000D-01
 -2.00000D-01                                                                          5.00000D+00
```

NUMERATORS OF TRANSFER FUNCTIONS /FES

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******************** ALFA/FES *****************
 2.28627D+04  3.22925D+05  7.39823D+05  4.12980D+05  9.22047D+04  1.68239D+04  1.89859D+03

     REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA         TAU

 -2.13785D-02  1.99105D-01  -4.27571D-02  4.01000D-02  1.06759D-01  2.00250D-01
 -2.00000D-01                                                                          5.00000D+00
 -4.53001D-01                                                                          2.20750D+00
 -2.00000D+00                                                                          5.00000D-01
 -1.14288D+01                                                                          8.74983D-02

******************** Q   /FES *****************
 2.50055D+05  7.82003D+05  6.72804D+05  2.34604D+05  3.39408D+04  1.61523D+03 -7.06847D-10

     REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA         TAU

  4.37614D-13                                                                         -2.28512D+12
 -9.36454D-02                                                                          1.06786D+01
 -2.00000D-01                                                                          5.00000D+00
 -3.80673D-01                                                                          2.62692D+00
 -4.53001D-01                                                                          2.20750D+00
 -2.00000D+00                                                                          5.00000D-01

******************** THET/FES *****************
 2.50055D+05  7.82003D+05  6.72804D+05  2.34604D+05  3.39408D+04  1.61523D+03

     REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA         TAU

 -9.36454D-02                                                                          1.06786D+01
 -2.00000D-01                                                                          5.00000D+00
 -3.80673D-01                                                                          2.62692D+00
 -4.53001D-01                                                                          2.20750D+00
 -2.00000D+00                                                                          5.00000D-01

******************** NZCG/FES *****************
-2.76507D+03 -8.81305D+03  5.10139D+03  3.14237D+04  1.72222D+04  2.07016D+03 -3.42704D+01 -8.54878D-11

     REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA         TAU

  1.89950D+00                                                                         -5.26453D-01
 -2.00000D+00                                                                          5.00000D-01
 -4.53001D-01                                                                          2.20750D+00
 -2.49417D-12                                                                          4.00936D+11
 -2.00000D-01                                                                          5.00000D+00
 -2.44849D+00                                                                          4.08415D-01
  1.47067D-02                                                                         -6.79961D+01
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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 4-2-2                                                    9 DEC 1983
                                                                                                2:27 PM

********************* CH. EQ.  ******************
 1.00000D+00  7.06210D+01  2.63225D+03  5.27981D+04  6.41205D+05  3.31258D+06  8.85527D+06  1.18804D+07  6.67028D+06  1.14012D+06
 4.31069D+04  8.37520D-12

     REAL            IMAG           -2*Z*W          O**2           ZETA          OMEGA          TAU

 -1.90263D+01    1.95207D+01    -3.80526D+01    7.43057D+02    6.97980D-01    2.72591D+01
 -5.24673D-02
 -8.20825D-01                                                                              1.90595D+01
 -2.14755D+00    1.73903D+00    -4.29510D+00    7.63637D+00    7.77140D-01    2.76340D+00   1.21829D+00
 -1.94289D-16
 -1.26000D+01    1.68000D+01    -2.52000D+01    4.41000D+02    6.00000D-01    2.10000D+01   5.14697D+15
 -2.00000D+00                                                                              5.00000D-01
 -2.00000D-01                                                                              5.00000D+00

                    NUMERATORS OF TRANSFER FUNCTIONS /FES

********************* ALFA/FES ******************
 2.53224D+04  3.66911D+05  9.45779D+05  6.99254D+05  1.59523D+05  2.99076D+04  3.79718D+03

     REAL            IMAG           -2*Z*W          O**2           ZETA          OMEGA          TAU

 -2.13785D-02    1.99105D-01    -4.27571D-02    4.01000D-02    1.06759D-01    2.00250D-01
 -2.00000D-01
 -8.17996D-01                                                                              5.00000D+00
 -2.00000D+00                                                                              1.22250D+00
 -1.14288D+01                                                                              5.00000D-01
                                                                                           8.74983D-02

********************* Q   /FES ******************
 2.76958D+05  1.05203D+06  1.27298D+06  6.00453D+05  9.57599D+04  3.72311D+03 -4.11239D-10

     REAL            IMAG           -2*Z*W          O**2           ZETA          OMEGA          TAU

  1.10456D-13
 -5.67659D-02                                                                             -9.05341D+12
 -2.00000D-01                                                                              1.76162D+01
 -7.23758D-01                                                                              5.00000D+00
 -8.17996D-01                                                                              1.38168D+00
 -2.00000D+00                                                                              1.22250D+00
                                                                                           5.00000D-01

********************* THET/FES ******************
 2.76958D+05  1.05203D+06  1.27298D+06  6.00453D+05  9.57599D+04  3.72311D+03

     REAL            IMAG           -2*Z*W          O**2           ZETA          OMEGA          TAU

 -5.67659D-02
 -2.00000D-01                                                                              1.76162D+01
 -7.23758D-01                                                                              5.00000D+00
 -8.17996D-01                                                                              1.38168D+00
 -2.00000D+00                                                                              1.22250D+00
                                                                                           5.00000D-01

********************* NZCG/FES ******************
-3.06256D+03 -1.08790D+04  1.28505D+04  6.93880D+04  5.33271D+04  7.96434D+03 -8.95806D+00 -4.97362D-11

     REAL            IMAG           -2*Z*W          O**2           ZETA          OMEGA          TAU

  2.57468D+00
 -2.00000D+00                                                                             -3.88398D-01
 -8.17996D-01                                                                              5.00000D-01
 -5.55231D-12                                                                              1.22250D+00
  1.11641D-03                                                                              1.80105D+11
 -2.00000D-01                                                                             -8.95725D+02
 -3.11007D+00                                                                              5.00000D+00
                                                                                           3.21536D-01
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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 4-3-7                                                              13 DEC 1983
                                                                                                             2:17 PM

******************** CH. EQ.  ******************
 1.000000D+00  7.090530D+01  2.652090D+03  5.353010D+04  6.556240D+05  3.483480D+06  9.666450D+06  1.382570D+07  8.631370D+06  1.452290D+06
 4.141660D+04  6.897260D-12
      REAL            IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -1.902660D+01   1.952070D+01  -3.805310D+01  7.430680D+02  6.979850D-01  2.725930D+01
  -2.113030D+00   1.726260D+00  -4.226060D+00  7.444850D+00  7.744220D-01  2.728530D+00
  -3.565140D-02
  -1.190460D+00                                                                            2.804940D+01
  -1.665330D-16                                                                            8.400100D-01
  -1.260000D+01   1.680000D+01  -2.520000D+01  4.410000D+02  6.000000D-01  2.100000D+01   6.004800D+15
  -2.000000D+00
  -2.000000D-01                                                                            5.000000D-01
                                                                                           5.000000D+00

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES ******************
 3.447150D+04  5.227290D+05  1.605390D+06  1.560320D+06  3.615610D+05  6.907560D+04  9.431710D+03
      REAL            IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -2.137850D-02   1.991050D-01  -4.275710D-02  4.010000D-02  1.067590D-01  2.002500D-01
  -2.000000D-01                                                                            5.000000D+00
  -1.492540D+00                                                                            6.700000D-01
  -2.000000D+00                                                                            5.000000D-01
  -1.142880D+01                                                                            8.749830D-02

******************** Q    /FES ******************
 3.770240D+05  1.794550D+06  2.889530D+06  1.762440D+06  2.952460D+05  8.917480D+03 -5.935620D-10
      REAL            IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

   6.656160D-14
  -3.851090D-02                                                                           -1.502370D+13
  -2.000000D-01                                                                            2.596670D+01
  -1.028740D+00                                                                            5.000000D+00
  -1.492540D+00                                                                            9.720670D-01
  -2.000000D+00                                                                            6.700000D-01
                                                                                           5.000000D-01

******************** THET/FES ******************
 3.770240D+05  1.794550D+06  2.889530D+06  1.762440D+06  2.952460D+05  8.917480D+03
      REAL            IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -3.851090D-02
  -2.000000D-01                                                                            2.596670D+01
  -1.028740D+00                                                                            5.000000D+00
  -1.492540D+00                                                                            9.720670D-01
  -2.000000D+00                                                                            6.700000D-01
                                                                                           5.000000D-01

******************** NZCG/FES ******************
-4.169070D+03 -1.762190D+04  2.287810D+04  1.607580D+05  1.694250D+05  2.735370D+04 -6.219170D+01 -7.178680D-11
      REAL            IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

   3.080580D+00
  -2.000000D+00                                                                           -3.246140D-01
  -1.492540D+00                                                                            5.000000D-01
  -2.000000D-01                                                                            6.700000D-01
  -1.154290D-12                                                                            5.000000D+00
   2.242400D-03                                                                            8.663340D+11
  -3.617110D+00                                                                           -4.459500D+02
                                                                                           2.764640D-01
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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 4-3-7-1

13 DEC 1983
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******************** CH. EQ. ******************

1.00000D+00 7.09053D+01 2.65209D+03 5.35301D+04 6.55624D+05 3.48348D+06 9.66645D+06 1.38257D+07 8.63137D+06 1.45229D+06
4.14166D+04 6.89726D-12

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
-1.90266D+01	1.95207D+01	-3.80531D+01	7.43068D+02	6.97985D-01	2.72593D+01	
-2.11303D+00	1.72626D+00	-4.22606D+00	7.44485D+00	7.74422D-01	2.72853D+00	
-3.56514D-02						2.80494D+01
-1.19046D+00						8.40010D-01
-1.66533D-16						6.00480D+15
-1.26000D+01	1.68000D+01	-2.52000D+01	4.41000D+02	6.00000D-01	2.10000D+01	
-2.00000D-01						5.00000D+00
-2.00000D+00						5.00000D-01

NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES ******************

3.44715D+04 5.15835D+05 1.50222D+06 1.25988D+06 1.09585D+05 4.71585D+04 -1.12759D-08

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
2.39106D-13						-4.18224D+12
-2.13785D-02	1.99105D-01	-4.27571D-02	4.01000D-02	1.06759D-01	2.00250D-01	
-1.49254D+00						6.70000D-01
-2.00000D+00						5.00000D-01
-1.14288D+01						8.74983D-02

******************** Q /FES ******************

3.77024D+05 1.71915D+06 2.54570D+06 1.25330D+06 4.45874D+04 0.0 -2.27415D-09

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
2.25840D-07						-4.42791D+06
-2.25842D-07						4.42788D+06
-3.85109D-02						2.59667D+01
-1.02874D+00						9.72067D-01
-1.49254D+00						6.70000D-01
-2.00000D+00						5.00000D-01

******************** THET/FES ******************

3.77024D+05 1.71915D+06 2.54570D+06 1.25330D+06 4.45874D+04 -1.94345D-08

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
4.35875D-13						-2.29424D+12
-3.85109D-02						2.59667D+01
-1.02874D+00						9.72067D-01
-1.49254D+00						6.70000D-01
-2.00000D+00						5.00000D-01

******************** NZCG/FES ******************

-4.16907D+03 -1.67881D+04 2.62357D+04 1.55510D+05 1.38323D+05 -3.10959D+02 1.36374D-09 -2.75041D-10

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
-1.94531D-10	9.40475D-07	-3.89062D-10	8.84493D-13	2.06843D-04	9.40475D-07	
2.24241D-03						-4.45950D+02
-1.49254D+00						6.70000D-01
-2.00000D+00						5.00000D-01
-3.61711D+00						2.76464D-01
3.08058D+00						-3.24614D-01

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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 5-1-1                                                    9 DEC 1983
                                                                                               2:27 PM

******************** CH. EQ.  *****************
 1.00000D+00  7.03173D+01  2.61105D+03  5.04214D+04  5.78156D+05  2.22788D+06  4.41843D+06  4.85128D+06  2.23740D+06  3.70279D+05
 1.69773D+04  2.59169D-12
    REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA          TAU

 -2.01075D+01  2.05153D+01  -4.02150D+01  8.25190D+02  6.99973D-01  2.87261D+01
 -7.39147D-02                                                                       1.35291D+01
 -4.99724D-01                                                                       2.00110D+00
 -1.06430D+00  1.42297D+00  -2.12860D+00  3.15759D+00  5.98944D-01  1.77696D+00
 -1.52656D-16                                                                       6.55069D+15
 -1.26000D+01  1.68000D+01  -2.52000D+01  4.41000D+02  6.00000D-01  2.10000D+01
 -2.00000D+00                                                                       5.00000D-01
 -2.00000D-01                                                                       5.00000D+00

                    NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 1.22781D+04  1.74199D+05  4.07924D+05  2.42096D+05  5.43377D+04  9.98184D+03  1.16191D+03
    REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA          TAU

 -2.13785D-02  1.99105D-01  -4.27571D-02  4.01000D-02  1.06759D-01  2.00250D-01
 -2.00000D-01                                                                       5.00000D+00
 -5.16221D-01                                                                       1.93716D+00
 -2.00000D+00                                                                       5.00000D-01
 -1.14288D+01                                                                       8.74983D-02

******************** Q   /FES *****************
 1.34289D+05  4.28454D+05  3.84024D+05  1.38549D+05  2.05040D+04  9.88494D+02 -1.33632D-11
    REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA          TAU

  1.35187D-14                                                                      -7.39716D+13
 -9.36454D-02                                                                       1.06786D+01
 -2.00000D-01                                                                       5.00000D+00
 -3.80673D-01                                                                       2.62692D+00
 -5.16221D-01                                                                       1.93716D+00
 -2.00000D+00                                                                       5.00000D-01

******************** THET/FES *****************
 1.34289D+05  4.28454D+05  3.84024D+05  1.38549D+05  2.05040D+04  9.88494D+02
    REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA          TAU

 -9.36454D-02                                                                       1.06786D+01
 -2.00000D-01                                                                       5.00000D+00
 -3.80673D-01                                                                       2.62692D+00
 -5.16221D-01                                                                       1.93716D+00
 -2.00000D+00                                                                       5.00000D-01

******************** NZCG/FES *****************
-1.48494D+03 -4.82681D+03  2.48294D+03  1.71651D+04  1.01847D+04  1.27258D+03 -2.09730D+01 -1.61617D-12
    REAL          IMAG          -2*Z*W        D**2          ZETA          OMEGA          TAU

  1.89950D+00                                                                      -5.26453D-01
 -2.00000D+00                                                                       5.00000D-01
 -5.16221D-01                                                                       1.93716D+00
 -2.00000D-01                                                                       5.00000D+00
 -7.68014D-14                                                                       1.30206D+13
 -2.44849D+00                                                                       4.08415D-01
  1.47067D-02                                                                      -6.79961D+01
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"*CBFREQ2*(12/9/83)-PITCH RATE CONFIG 5-2-2                                                                          9 DEC 1983
                                                                                                                     2:27 PM

********************* CH. EQ.  *****************
 1.00000D+00  7.06210D+01  2.63225D+03  5.12039D+04  5.93090D+05  2.39647D+06  5.01990D+06  5.98112D+06  3.31939D+06  5.61137D+05
 1.99986D+04  0.0

      REAL            IMAG            -2*Z*W          D**2            ZETA            OMEGA           TAU

  -2.01076D+01    2.05153D+01    -4.02153D+01    8.25195D+02     6.99975D-01     2.87262D+01
  -1.01327D+00    1.42499D+00    -2.02654D+00    3.05730D+00     5.79503D-01     1.74851D+00
  -4.82721D-02                                                                                   2.07159D+01
  -9.30914D-01                                                                                   1.07421D+00
   0.0                                                                                           0.0
  -1.26000D+01    1.68000D+01    -2.52000D+01    4.41000D+02     6.00000D-01     2.10000D+01
  -2.00000D+00                                                                                   5.00000D-01
  -2.00000D-01                                                                                   5.00000D+00

                        NUMERATORS OF TRANSFER FUNCTIONS /FES

********************* ALFA/FES *****************
 1.25702D+04  1.83547D+05  4.88777D+05  3.84029D+05  8.79494D+04  1.65671D+04  2.14357D+03

      REAL            IMAG            -2*Z*W          D**2            ZETA            OMEGA           TAU

  -2.13785D-02    1.99105D-01    -4.27571D-02    4.01000D-02     1.06759D-01     2.00250D-01
  -2.00000D-01                                                                                   5.00000D+00
  -9.30233D-01                                                                                   1.07500D+00
  -2.00000D+00                                                                                   5.00000D-01
  -1.14288D+01                                                                                   8.74983D-02

********************* Q   /FES *****************
 1.37483D+05  5.37664D+05  6.77906D+05  3.31371D+05  5.37480D+04  2.10176D+03 -1.09532D-10

      REAL            IMAG            -2*Z*W          D**2            ZETA            OMEGA           TAU

   5.21147D-14                                                                                  -1.91884D+13
  -5.67659D-02                                                                                   1.76162D+01
  -2.00000D-01                                                                                   5.00000D+00
  -7.23758D-01                                                                                   1.38168D+00
  -9.30233D-01                                                                                   1.07500D+00
  -2.00000D+00                                                                                   5.00000D-01

********************* THET/FES *****************
 1.37483D+05  5.37664D+05  6.77906D+05  3.31371D+05  5.37480D+04  2.10176D+03

      REAL            IMAG            -2*Z*W          D**2            ZETA            OMEGA           TAU

  -5.67659D-02                                                                                   1.76162D+01
  -2.00000D-01                                                                                   5.00000D+00
  -7.23758D-01                                                                                   1.38168D+00
  -9.30233D-01                                                                                   1.07500D+00
  -2.00000D+00                                                                                   5.00000D-01

********************* NZCG/FES *****************
-1.52027D+03 -5.57104D+03  5.91248D+03  3.55421D+04  2.94399D+04  4.49674D+03 -5.05697D+00 -1.32471D-11

      REAL            IMAG            -2*Z*W          D**2            ZETA            OMEGA           TAU

   2.57468D+00                                                                                  -3.88398D-01
  -2.00000D+00                                                                                   5.00000D-01
  -9.30233D-01                                                                                   1.07500D+00
  -2.61982D-12                                                                                   3.81706D+11
   1.11641D-03                                                                                  -8.95725D+02
  -2.00000D-01                                                                                   5.00000D+00
  -3.11007D+00                                                                                   3.21536D-01
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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 6-1-1                                                   9 DEC 1983
                                                                                               2:27 PM

******************** CH. EQ.  *****************
 1.00000D+00  6.83173D+01  2.47442D+03  4.54726D+04  4.88805D+05  1.29471D+06  2.64188D+06  1.50760D+06  2.72941D+05  1.35013D+04
 2.99789D-12  0.0
     REAL          IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -2.01570D+01   2.05118D+01   -4.03140D+01   8.27040D+02   7.00911D-01   2.87583D+01
  -1.03772D+00   2.02006D+00   -2.07544D+00   5.15753D+00   4.56941D-01   2.27102D+00
  -8.01690D-02                                                                            1.24737D+01
  -4.47644D-01                                                                            2.23392D+00
  -2.22045D-16                                                                            4.50360D+15
  -1.26000D+01   1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
  -2.00000D-01                                                                            5.00000D+00
   0.0                                                                                    0.0

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 1.15261D+04  1.69106D+05  4.36123D+05  1.04119D+05  2.05603D+04  3.16942D+03  0.0
     REAL          IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -1.14288D+01                                                                            8.74983D-02
  -3.00000D+00                                                                            3.33333D-01
  -2.13785D-02   1.99105D-01   -4.27571D-02   4.01000D-02   1.06759D-01   2.00250D-01
  -2.00000D-01                                                                            5.00000D+00
   0.0                                                                                    0.0

******************** Q    /FES *****************
 1.26065D+05  4.63201D+05  2.71476D+05  5.02576D+04  2.69639D+03 -6.20501D-09  0.0
     REAL          IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -3.00000D+00                                                                            3.33333D-01
  -3.80673D-01                                                                            2.62692D+00
  -2.00000D-01                                                                            5.00000D+00
  -9.36454D-02                                                                            1.06786D+01
   2.30123D-12                                                                           -4.34551D+11
   0.0                                                                                    0.0

******************** THET/FES *****************
 1.26065D+05  4.63201D+05  2.71476D+05  5.02576D+04  2.69639D+03  0.0
     REAL          IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -3.00000D+00                                                                            3.33333D-01
  -3.80673D-01                                                                            2.62692D+00
  -2.00000D-01                                                                            5.00000D+00
  -9.36454D-02                                                                            1.06786D+01
   0.0                                                                                    0.0

******************** NZCG/FES *****************
-1.39400D+03 -5.20558D+03  3.27491D+03  2.02406D+04  3.59166D+03 -5.72095D+01 -7.50449D-10  0.0
     REAL          IMAG          -2*Z*W         D**2          ZETA          OMEGA          TAU

  -3.00000D+00                                                                            3.33333D-01
  -2.44849D+00                                                                            4.08415D-01
   1.89950D+00                                                                           -5.26453D-01
  -2.00000D-01                                                                            5.00000D+00
   1.47067D-02                                                                           -6.79961D+01
  -1.31176D-11                                                                            7.62337D+10
   0.0                                                                                    0.0
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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 6-1-1-1                                            13 DEC 1983
                                                                                          2:17 PM

********************* CH. EQ.  *****************
 1.00000D+00  6.83173D+01  2.47442D+03  4.54726D+04  4.88805D+05  1.29471D+06  2.64188D+06  1.50760D+06  2.72941D+05  1.35013D+04
 2.99789D-12  0.0
      REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -2.01570D+01  2.05118D+01  -4.03140D+01  8.27040D+02  7.00911D-01  2.87583D+01
  -1.03772D+00  2.02006D+00  -2.07544D+00  5.15753D+00  4.56941D-01  2.27102D+00
  -8.01690D-02                                                                  1.24737D+01
  -4.47644D-01                                                                  2.23392D+00
  -2.22045D-16                                                                  4.50360D+15
  -1.26000D+01  1.68000D+01  -2.52000D+01  4.41000D+02  6.00000D-01  2.10000D+01
  -2.00000D-01                                                                  5.00000D+00
   0.0                                                                          0.0

                          NUMERATORS OF TRANSFER FUNCTIONS /FES

********************* ALFA/FES *****************
 1.15261D+04  1.66801D+05  4.02763D+05  2.35661D+04  1.58471D+04  1.30096D-07  0.0
      REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -1.14288D+01                                                                  8.74983D-02
  -3.00000D+00                                                                  3.33333D-01
  -2.13785D-02  1.99105D-01  -4.27571D-02  4.01000D-02  1.06759D-01  2.00250D-01
  -8.20946D-12                                                                  1.21811D+11
   0.0                                                                          0.0

********************* Q   /FES *****************
 1.26065D+05  4.37988D+05  1.83878D+05  1.34820D+04  0.0          6.91958D-08  0.0
      REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -3.00000D+00                                                                  3.33333D-01
  -3.80673D-01                                                                  2.62692D+00
  -9.36454D-02                                                                  1.06786D+01
   3.50005D-11  2.26550D-06  7.00011D-11  5.13248D-12  -1.54494D-05  2.26550D-06
   0.0                                                                          0.0

********************* THET/FES *****************
 1.26065D+05  4.37988D+05  1.83878D+05  1.34820D+04 -2.08875D-10  0.0
      REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -3.00000D+00                                                                  3.33333D-01
  -3.80673D-01                                                                  2.62692D+00
  -9.36454D-02                                                                  1.06786D+01
   1.54930D-14                                                                 -6.45455D+13
   0.0                                                                          0.0

********************* NZCG/FES *****************
-1.39400D+03 -4.92678D+03  4.26027D+03  1.93885D+04 -2.86048D+02 -1.57341D-08  8.36871D-09  0.0
      REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -3.00000D+00                                                                  3.33333D-01
  -2.44849D+00                                                                  4.08415D-01
   1.89950D+00                                                                 -5.26453D-01
   1.47067D-02                                                                 -6.79961D+01
   5.40988D-06                                                                 -1.84847D+05
  -5.40795D-06                                                                  1.84913D+05
   0.0                                                                          0.0
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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 6-2-1

9 DEC 1983
2:27 PM

******************** CH. EQ. ******************
1.00000D+00 7.13173D+01 2.67937D+03 5.28958D+04 6.25223D+05 2.76112D+06 6.52600D+06 9.43324D+06 4.79573D+06 8.32323D+05
4.05039D+04 8.99368D-12

REAL	IMAG	-2*Z*W	W**2	ZETA	OMEGA	TAU
ACT -2.01570D+01	2.05118D+01	-4.03140D+01	8.27040D+02	7.00911D-01	2.87583D+01	
SP -1.03772D+00	2.02006D+00	-2.07544D+00	5.15753D+00	4.56941D-01	2.27102D+00	
X -8.01690D-02						1.24737D+01
-4.47644D-01 - λ_L						2.23392D+00
-2.22045D-16 ~O						4.50360D+15
Feel -1.26000D+01	1.68000D+01	-2.52000D+01	4.41000D+02	6.00000D-01	2.10000D+01	
-3.00000D+00 - T_T						3.33333D-01
[redacted] T_w						5.00000D+00

NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES ******************
1.88553D+04 2.85406D+05 8.42108D+05 5.02157D+05 1.12855D+05 2.08285D+04 2.41152D+03

REAL	IMAG	-2*Z*W	W**2	ZETA	OMEGA	TAU
-2.13785D-02	1.99105D-01	-4.27571D-02	4.01000D-02	1.06759D-01	2.00250D-01	
-2.00000D-01						5.00000D+00
-4.65116D-01						2.15000D+00
-3.00000D+00						3.33333D-01
-1.14288D+01						8.74983D-02

******************** Q /FES ******************
2.06225D+05 8.53655D+05 7.96535D+05 2.88773D+05 4.26504D+04 2.05160D+03 -6.76523D-10

REAL	IMAG	-2*Z*W	W**2	ZETA	OMEGA	TAU
3.29754D-13 ~O						-3.03257D+12
-9.36454D-02 - $Y_{T\theta_1}$						1.06786D+01
[redacted] Cancels Tw						5.00000D+00
-3.80673D-01 - $Y_{T\theta_L}$						2.62692D+00
-4.65116D-01 - T_E						2.15000D+00
-3.00000D+00 - K_I						3.33333D-01

******************** THET/FES ******************
2.06225D+05 8.53655D+05 7.96535D+05 2.88773D+05 4.26504D+04 2.05160D+03

REAL	IMAG	-2*Z*W	W**2	ZETA	OMEGA	TAU
-9.36454D-02						1.06786D+01
-2.00000D-01						5.00000D+00
-3.80673D-01						2.62692D+00
-4.65116D-01						2.15000D+00
-3.00000D+00						3.33333D-01

******************** NZCG/FES ******************
-2.28040D+03 -9.57631D+03 1.39656D+03 3.56027D+04 2.12759D+04 2.63920D+03 -4.35290D+01 -8.18203D-11

REAL	IMAG	-2*Z*W	W**2	ZETA	OMEGA	TAU
1.89950D+00						-5.26453D-01
-2.44849D+00						4.08415D-01
-4.65116D-01						2.15000D+00
-1.87940D-12						5.32084D+11
-2.00000D-01						5.00000D+00
-3.00000D+00						3.33333D-01
1.47067D-02						-6.79961D+01

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*#CBFREQ2*(12/9/83)-PITCH RATE CONFIG 6-2-1-1                                                    9 DEC 1983
                                                                                                  2:27 PM

******************** CH. EQ.  *****************
 1.00000D+00  7.13173D+01  2.67937D+03  5.28958D+04  6.25223D+05  2.76112D+06  6.52600D+06  9.43324D+06  4.79573D+06  8.32323D+05
 4.05039D+04  8.99368D-12
     REAL          IMAG          -2*Z*W        O**2         ZETA         OMEGA        TAU

  -2.01570D+01  2.05113D+01   -4.03140D+01  8.27040D+02  7.00911D-01  2.87583D+01
  -1.03772D+00  2.02006D+00   -2.07544D+00  5.15753D+00  4.56941D-01  2.27102D+00
  -8.01690D-02                                                                      1.24737D+01
  -4.47644D-01                                                                      2.23392D+00
  -2.22045D-16                                                                      4.50360D+15
  -1.26000D+01  1.68000D+01   -2.52000D+01  4.41000D+02  6.00000D-01  2.10000D+01
  -2.00000D-01                                                                      5.00000D+00
  -3.00000D+00                                                                      3.33333D-01

                        NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 1.88553D+04  2.81635D+05  7.85781D+05  3.45001D+05  4.38545D+04  1.20576D+04  6.81309D-10
     REAL          IMAG          -2*Z*W        O**2         ZETA         OMEGA        TAU

  -5.65046D-14                                                                      1.76977D+13
  -2.13785D-02  1.99105D-01   -4.27571D-02  4.01000D-02  1.06759D-01  2.00250D-01
  -4.65116D-01                                                                      2.15000D+00
  -3.00000D+00                                                                      3.33333D-01
  -1.14288D+01                                                                      8.74983D-02

******************** Q    /FES *****************
 2.06225D+05  8.12410D+05  6.34053D+05  1.61962D+05  1.02580D+04  0.0          4.40401D-12
     REAL          IMAG          -2*Z*W        O**2         ZETA         OMEGA        TAU

   3.38926D-15  2.07201D-08    6.77852D-15  4.29324D-16 -1.63573D-07  2.07201D-08
  -9.36454D-02                                                                      1.06786D+01
  -3.80673D-01                                                                      2.62692D+00
  -4.65116D-01                                                                      2.15000D+00
  -3.00000D+00                                                                      3.33333D-01

******************** THET/FES *****************
 2.06225D+05  8.12410D+05  6.34053D+05  1.61962D+05  1.02580D+04 -6.09519D-10
     REAL          IMAG          -2*Z*W        O**2         ZETA         OMEGA        TAU

   5.94108D-14                                                                     -1.68320D+13
  -9.36454D-02                                                                      1.06786D+01
  -3.80673D-01                                                                      2.62692D+00
  -4.65116D-01                                                                      2.15000D+00
  -3.00000D+00                                                                      3.33333D-01

******************** NZCG/FES *****************
-2.28040D+03 -9.12023D+03  3.22061D+03  3.49586D+04  1.42842D+04 -2.17645D+02 -8.23991D-11  5.32631D-13
     REAL          IMAG          -2*Z*W        O**2         ZETA         OMEGA        TAU

   1.89950D+00                                                                     -5.26453D-01
  -2.44849D+00                                                                      4.08415D-01
  -4.65116D-01                                                                      2.15000D+00
   4.94696D-08                                                                     -2.02144D+07
  -4.94698D-08                                                                      2.02144D+07
  -3.00000D+00                                                                      3.33333D-01
   1.47067D-02                                                                     -6.79961D+01
IHO900I EXECUTION TERMINATING DUE TO ERROR COUNT FOR ERROR NUMBER  222

IHO222I NAMEL - NAME NOT IN NAMELIST DICTIONARY. NAME=       TI

TI=0..0.5.0.55.15.. HH=5..5..0..0..
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"#C3FREQ2"(12/9/83)-PITCH RATE CONFIG 7-1-4                                                      9 DEC 1983
                                                                                                  2:27 PM

******************** CH. EQ.  *****************
 1.00000D+00  6.86496D+01  2.49741D+03  4.74760D+04  5.34072D+05  1.98234D+06  3.17348D+06  6.97241D+05  1.00946D+05  1.46836D+04
 0.0          0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -1.92847D+01   1.98029D+01   -3.85694D+01   7.64054D+02   6.97671D-01   2.76415D+01
  -2.32402D+00   1.63821D+00   -4.64805D+00   8.08480D+00   8.17346D-01   2.84338D+00
  -1.60657D-02   1.63379D-01   -3.21315D-02   2.69506D-02   9.78624D-02   1.64167D-01
  -2.00000D-01                                                                              5.00000D+00
  -1.26000D+01   1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
   0.0                                                                                       0.0
   0.0                                                                                       0.0


                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 1.92102D+04  2.24213D+05  5.42319D+04  1.08355D+04  1.76079D+03  0.0          0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -1.14288D+01
  -2.13735D-02   1.99105D-01   -4.27571D-02   4.01000D-02   1.06759D-01   2.00250D-01   8.74983D-02
  -2.00000D-01                                                                              5.00000D+00
   0.0                                                                                       0.0
   0.0                                                                                       0.0

******************** Q   /FES *****************
 2.10108D+05  2.03295D+05  4.04548D+04  1.64002D+03  0.0          0.0          0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -7.12825D-01                                                                              1.40287D+00
  -2.00000D-01                                                                              5.00000D+00
  -5.47512D-02                                                                              1.82644D+01
   0.0                                                                                       0.0
   0.0                                                                                       0.0
   0.0                                                                                       0.0

******************** THET/FES *****************
 2.10108D+05  2.03295D+05  4.04548D+04  1.64002D+03  0.0          0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -7.12825D-01                                                                              1.40287D+00
  -2.00000D-01                                                                              5.00000D+00
  -5.47512D-02                                                                              1.82644D+01
   0.0                                                                                       0.0
   0.0                                                                                       0.0

******************** NZCG/FES *****************
-2.32333D+03 -1.70598D+03  1.80281D+04  3.58223D+03 -1.46067D+01  0.0          0.0          0.0
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -3.08635D+00                                                                              3.24007D-01
   2.54808D+00                                                                             -3.92453D-01
  -2.00000D-01                                                                              5.00000D+00
   3.99717D-03                                                                             -2.50177D+02
   0.0                                                                                       0.0
   0.0                                                                                       0.0
   0.0                                                                                       0.0
```

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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 8-1-5                                  13 DEC 1983
                                                                              2:17 PM

********************* CH. EQ.  ******************
 1.00000D+00  7.02890D+01  2.60907D+03  4.99381D+04  5.64579D+05  1.98226D+06  3.48576D+06  3.62560D+06  1.71167D+06  2.83981D+05
 1.23556D+04 -6.85875D-13

      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -2.03540D+01   2.07570D+01  -4.07080D+01   8.45138D+02   7.00141D-01   2.90713D+01
  -6.68974D-02                                                                         1.49483D+01
  -5.85509D-01                                                                         1.70791D+00
  -7.64299D-01   1.23764D+00  -1.52860D+00   2.11590D+00   5.25431D-01   1.45461D+00
   5.55112D-17                                                                        -1.80144D+16
  -1.26000D+01   1.68000D+01  -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
  -2.00000D+00                                                                         5.00000D-01
  -2.00000D-01                                                                         5.00000D+00

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

********************* ALFA/FES ******************
 2.45061D+04  2.03798D+05  4.26742D+05  2.60652D+05  5.74878D+04  1.03450D+04  1.23556D+03
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -1.96040D-02   1.95010D-01  -3.92080D-02   3.84132D-02   1.00024D-01   1.95993D-01
  -2.00000D-01                                                                         5.00000D+00
  -5.99000D-01                                                                         1.66945D+00
  -2.00000D+00                                                                         5.00000D-01
  -5.47803D+00                                                                         1.82547D-01

********************* Q    /FES ******************
 1.22113D+05  4.02766D+05  3.84937D+05  1.46619D+05  2.23555D+04  1.08047D+03 -2.95804D-11
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

   2.73773D-14                                                                        -3.65266D+13
  -9.02839D-02                                                                         1.10762D+01
  -2.00000D-01                                                                         5.00000D+00
  -4.09031D-01                                                                         2.44480D+00
  -5.99000D-01                                                                         1.66945D+00
  -2.00000D+00                                                                         5.00000D-01

********************* THET/FES ******************
 1.22113D+05  4.02766D+05  3.84937D+05  1.46619D+05  2.23555D+04  1.08047D+03
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -9.02839D-02                                                                         1.10762D+01
  -2.00000D-01                                                                         5.00000D+00
  -4.09031D-01                                                                         2.44480D+00
  -5.99000D-01                                                                         1.66945D+00
  -2.00000D+00                                                                         5.00000D-01

********************* NZCG/FES ******************
-2.96382D+03 -9.87925D+03 -2.89975D+03  1.50313D+04  1.07798D+04  1.45258D+03 -1.87569D+01 -3.57753D-12
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

   1.24448D+00                                                                        -8.03546D-01
  -5.99000D-01                                                                         1.66945D+00
  -1.90716D-13                                                                         5.24340D+12
  -1.79062D+00                                                                         5.58467D-01
   1.18531D-02                                                                        -8.43664D+01
  -2.00000D+00                                                                         5.00000D-01
  -2.00000D-01                                                                         5.00000D+00
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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 8-1-5-1                                                      13 DEC 1983
                                                                                                    2:17 PM

******************** CH. EQ. *****************
 1.000000D+00  7.02890D+01  2.60907D+03  4.99381D+04  5.64579D+05  1.98226D+06  3.48576D+06  3.62560D+06  1.71167D+06  2.83981D+05
 1.23556D+04 -6.85875D-13
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

 -2.03540D+01   2.07570D+01   -4.07080D+01   8.45138D+02   7.00141D-01   2.90713D+01
 -6.68974D-02                                                                         1.49483D+01
 -5.85509D-01                                                                         1.70791D+00
 -7.64299D-01   1.23764D+00   -1.52860D+00   2.11590D+00   5.25431D-01   1.45461D+00
  5.55112D-17                                                                        -1.80144D+16
 -1.26000D+01   1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
 -2.00000D-01                                                                         5.00000D+00
 -2.00000D+00                                                                         5.00000D-01

                        NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 2.45061D+04  1.98897D+05  3.86963D+05  1.83260D+05  2.08358D+04  6.17782D+03 -1.07265D-09
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  1.73629D-13                                                                        -5.75942D+12
 -1.96040D-02   1.95010D-01   -3.92080D-02   3.84132D-02   1.00024D-01   1.95993D-01
 -5.99000D-01                                                                         1.66945D+00
 -2.00000D+00                                                                         5.00000D-01
 -5.47803D+00                                                                         1.82547D-01

******************** Q   /FES *****************
 1.22113D+05  3.78343D+05  3.09268D+05  8.47654D+04  5.40237D+03  0.0          7.31623D-10
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  1.06245D-12   3.68003D-07    2.12489D-12   1.35426D-13  -2.88706D-06   3.68003D-07
 -9.02839D-02                                                                         1.10762D+01
 -4.09031D-01                                                                         2.44480D+00
 -5.99000D-01                                                                         1.66945D+00
 -2.00000D+00                                                                         5.00000D-01

******************** THET/FES *****************
 1.22113D+05  3.78343D+05  3.09268D+05  8.47654D+04  5.40237D+03  3.16187D-11
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

 -5.85274D-15                                                                         1.70860D+14
 -9.02839D-02                                                                         1.10762D+01
 -4.09031D-01                                                                         2.44480D+00
 -5.99000D-01                                                                         1.66945D+00
 -2.00000D+00                                                                         5.00000D-01

******************** NZCG/FES *****************
-2.96382D+03 -9.28649D+03 -1.04245D+03  1.52398D+04  7.73180D+03 -9.37846D+01  1.29728D-10  8.84842D-11
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  1.24448D+00                                                                        -8.03546D-01
 -1.79062D+00                                                                         5.58467D-01
 -5.99000D-01                                                                         1.66945D+00
 -2.00000D+00                                                                         5.00000D-01
  9.71370D-07                                                                        -1.02947D+06
 -9.71291D-07                                                                         1.02956D+06
  1.18531D-02                                                                        -8.43664D+01
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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 8-2-5                                                  13 DEC 1983
                                                                                              2:17 PM

******************** CH. EQ.  *****************
 1.000000D+00  7.02890D+01  2.609070D+03  4.954350D+04  5.527800D+05  1.758750D+06  2.597600D+06  2.385230D+06  1.122570D+06  1.833160D+05
 7.213920D+03 -5.005660D-13
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -2.057820D+01  2.098430D+01  -4.115650D+01  8.638060D+02  7.001650D-01  2.939060D+01
  -4.877170D-01  9.743630D-01  -9.754350D-01  1.187250D+00  4.476070D-01  1.089610D+00
  -5.695850D-02                                                                          1.755660D+01
  -7.000920D-01                                                                          1.428380D+00
   6.938890D-17                                                                         -1.441150D+16
  -1.260000D+01  1.680000D+01  -2.520000D+01  4.410000D+02  6.000000D-01  2.100000D+01
  -2.000000D+00                                                                          5.000000D-01
  -2.000000D-01                                                                          5.000000D+00

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 1.270680D+04  1.107690D+05  2.605960D+05  2.003290D+05  4.496410D+04  8.239030D+03  1.069550D+03
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -1.960400D-02  1.950100D-01  -3.920800D-02  3.841320D-02  1.000240D-01  1.959930D-01
  -2.000000D-01                                                                          5.000000D+00
  -1.000000D+00                                                                          1.000000D+00
  -2.000000D+00                                                                          5.000000D-01
  -5.478030D+00                                                                          1.825470D-01

******************** Q   /FES *****************
 6.331760D+04  2.342320D+05  2.681340D+05  1.150100D+05  1.872560D+04  9.353020D+02  8.042760D-11
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -8.599110D-14                                                                          1.162910D+13
  -9.028390D-02                                                                          1.107620D+01
  -2.000000D-01                                                                          5.000000D+00
  -4.090310D-01                                                                          2.444800D+00
  -1.000000D+00                                                                          1.000000D+00
  -2.000000D+00                                                                          5.000000D-01

******************** THET/FES *****************
 6.331760D+04  2.342320D+05  2.681340D+05  1.150100D+05  1.872560D+04  9.353020D+02
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

  -9.028390D-02                                                                          1.107620D+01
  -2.000000D-01                                                                          5.000000D+00
  -4.090310D-01                                                                          2.444800D+00
  -1.000000D+00                                                                          1.000000D+00
  -2.000000D+00                                                                          5.000000D-01

******************** NZCG/FES *****************
-1.536800D+03 -5.738830D+03 -3.188590D+03  8.200410D+03  8.471480D+03  1.268280D+03 -1.623680D+01  9.727110D-12
      REAL          IMAG          -2*Z*W        O**2          ZETA          OMEGA         TAU

   1.244480D+00                                                                         -8.035460D-01
   5.990980D-13                                                                         -1.669180D+12
   1.185310D-02                                                                         -8.436640D+01
  -2.000000D-01                                                                          5.000000D+00
  -1.790620D+00                                                                          5.584670D-01
  -2.000000D+00                                                                          5.000000D-01
  -1.000000D+00                                                                          1.000000D+00
```

"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 8-2-5-1 13 DEC 1983 2:17 PM

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******************** CH. EQ. *****************
1.00000D+00  7.02890D+01  2.60907D+03  4.95435D+04  5.52780D+05  1.75875D+06  2.59760D+06  2.38523D+06  1.12257D+06  1.83316D+05
7.21392D+03 -5.00566D-13
```

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
-2.05782D+01	2.09843D+01	-4.11565D+01	8.63806D+02	7.00165D-01	2.93906D+01	
-4.87717D-01	9.74363D-01	-9.75435D-01	1.18725D+00	4.47607D-01	1.08961D+00	
-5.69585D-02						1.75566D+01
-7.00092D-01						1.42838D+00
6.93889D-17						-1.44115D+16
-1.26000D+01	1.68000D+01	-2.52000D+01	4.41000D+02	6.00000D-01	2.10000D+01	
-2.00000D+00						5.00000D-01
-2.00000D-01						5.00000D+00

NUMERATORS OF TRANSFER FUNCTIONS /FES

```
******************** ALFA/FES *****************
1.27068D+04  1.08227D+05  2.38951D+05  1.52539D+05  1.44563D+04  5.34777D+03 -7.86756D-09
```

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
1.47119D-12						-6.79724D+11
-1.96040D-02	1.95010D-01	-3.92080D-02	3.84132D-02	1.00024D-01	1.95993D-01	
-1.00000D+00						1.00000D+00
-2.00000D+00						5.00000D-01
-5.47803D+00						1.82547D-01

```
******************** Q   /FES *****************
6.33176D+04  2.21568D+05  2.23820D+05  7.02457D+04  4.67651D+03  0.0         6.05206D-10
```

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
9.71962D-13	3.59742D-07	1.94392D-12	1.29414D-13	-2.70183D-06	3.59742D-07	
-9.02839D-02						1.10762D+01
-4.09031D-01						2.44480D+00
-1.00000D+00						1.00000D+00
-2.00000D+00						5.00000D-01

```
******************** THET/FES *****************
6.33176D+04  2.21568D+05  2.23820D+05  7.02457D+04  4.67651D+03  4.76875D-11
```

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
-1.01972D-14						9.80657D+13
-9.02839D-02						1.10762D+01
-4.09031D-01						2.44480D+00
-1.00000D+00						1.00000D+00
-2.00000D+00						5.00000D-01

```
******************** NZCG/FES *****************
-1.53680D+03 -5.43147D+03 -2.10229D+03  8.62087D+03  6.74730D+03 -8.11838D+01  9.51522D-10  7.31950D-11
```

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
1.24448D+00						-8.03546D-01
-9.49481D-07						1.05321D+06
9.49568D-07						-1.05311D+06
1.18531D-02						-8.43664D+01
-1.79062D+00						5.58467D-01
-1.00000D+00						1.00000D+00
-2.00000D+00						5.00000D-01

"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 8-3-5

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******************** CH. EQ. ******************

1.00000D+00 7.02890D+01 2.60907D+03 4.99381D+04 5.64579D+05 1.98226D+06 3.48576D+06 3.62560D+06 1.71167D+06 2.83981D+05
1.23556D+04 -6.85875D-13

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
-2.03540D+01	2.07570D+01	-4.07080D+01	8.45138D+02	7.00141D-01	2.90713D+01	
-6.68974D-02						1.49483D+01
-5.85509D-01						1.70791D+00
-7.64299D-01	1.23764D+00	-1.52860D+00	2.11590D+00	5.25431D-01	1.45461D+00	
5.55112D-17						-1.80144D+16
-1.26000D+01	1.68000D+01	-2.52000D+01	4.41000D+02	6.00000D-01	2.10000D+01	
-2.00000D+00						5.00000D-01
-2.00000D-01						5.00000D+00

NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES ******************

1.27068D+04 1.17090D+05 3.09382D+05 2.81190D+05 6.37670D+04 1.18058D+04 1.60166D+03

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
-1.96040D-02	1.95010D-01	-3.92080D-02	3.84132D-02	1.00024D-01	1.95993D-01	
-2.00000D-01						5.00000D+00
-1.49750D+00						6.67780D-01
-2.00000D+00						5.00000D-01
-5.47803D+00						1.82547D-01

******************** Q /FES ******************

6.33176D+04 2.65732D+05 3.53163D+05 1.63376D+05 2.75763D+04 1.40061D+03 5.89898D-11

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
-4.21171D-14						2.37433D+13
-9.02839D-02						1.10762D+01
-2.00000D-01						5.00000D+00
-4.09031D-01						2.44480D+00
-1.49750D+00						6.67780D-01
-2.00000D+00						5.00000D-01

******************** THET/FES ******************

6.33176D+04 2.65732D+05 3.53163D+05 1.63376D+05 2.75763D+04 1.40061D+03

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
-9.02839D-02						1.10762D+01
-2.00000D-01						5.00000D+00
-4.09031D-01						2.44480D+00
-1.49750D+00						6.67780D-01
-2.00000D+00						5.00000D-01

******************** NZCG/FES ******************

-1.53680D+03 -6.50339D+03 -5.27910D+03 8.70460D+03 1.20470D+04 1.90732D+03 -2.43145D+01 7.13437D-12

REAL	IMAG	-2*Z*W	O**2	ZETA	OMEGA	TAU
1.24448D+00						-8.03546D-01
2.93431D-13						-3.40795D+12
1.18531D-02						-8.43664D+01
-2.00000D-01						5.00000D+00
-2.00000D+00						5.00000D-01
-1.79062D+00						5.58467D-01
-1.49750D+00						6.67780D-01

```
"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 8-3-5-1                                                    13 DEC 1983
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******************** CH. EQ.  *****************
 1.00000D+00  7.02890D+01  2.60907D+03  4.99381D+04  5.64579D+05  1.98226D+06  3.48576D+06  3.62560D+06  1.71167D+06  2.83981D+05
 1.23556D+04 -6.85875D-13
       REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -2.03540D+01   2.07570D+01   -4.07080D+01   8.45138D+02   7.00141D-01   2.90713D+01
  -6.68974D-02                                                                          1.49483D+01
  -5.85509D-01                                                                          1.70791D+00
  -7.64299D-01   1.23764D+00   -1.52860D+00   2.11590D+00   5.25431D-01   1.45461D+00
   5.55112D-17                                                                         -1.80144D+16
  -1.26000D+01   1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
  -2.00000D+00                                                                          5.00000D-01
  -2.00000D-01                                                                          5.00000D+00

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 1.27068D+04  1.14549D+05  2.86472D+05  2.23896D+05  1.89878D+04  8.00828D+03 -7.12427D-09
       REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

   8.89613D-13                                                                         -1.12408D+12
  -1.96040D-02   1.95010D-01   -3.92080D-02   3.84132D-02   1.00024D-01   1.95993D-01
  -1.49750D+00                                                                          6.67780D-01
  -2.00000D+00                                                                          5.00000D-01
  -5.47803D+00                                                                          1.82547D-01

******************** Q   /FES *****************
 6.33176D+04  2.53069D+05  3.02550D+05  1.02866D+05  7.00307D+03  0.0          9.86497D-10
       REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

   1.03458D-12   3.75322D-07   2.06915D-12   1.40866D-13  -2.75650D-06   3.75322D-07
  -9.02839D-02                                                                          1.10762D+01
  -4.09031D-01                                                                          2.44480D+00
  -1.49750D+00                                                                          6.67780D-01
  -2.00000D+00                                                                          5.00000D-01

******************** THET/FES *****************
 6.33176D+04  2.53069D+05  3.02550D+05  1.02866D+05  7.00307D+03  4.56327D-09
       REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

  -6.51610D-13                                                                          1.53466D+12
  -9.02839D-02                                                                          1.10762D+01
  -4.09031D-01                                                                          2.44480D+00
  -1.49750D+00                                                                          6.67780D-01
  -2.00000D+00                                                                          5.00000D-01

******************** NZCG/FES *****************
-1.53680D+03 -6.19603D+03 -4.03989D+03  9.51258D+03  1.01445D+04 -1.21573D+02  8.61626D-10  1.19309D-10
       REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA          TAU

   1.24448D+00                                                                         -8.03546D-01
  -9.90603D-07                                                                          1.00949D+06
   9.90692D-07                                                                         -1.00940D+06
   1.18531D-02                                                                         -8.43664D+01
  -1.79062D+00                                                                          5.58467D-01
  -2.00000D+00                                                                          5.00000D-01
  -1.49750D+00                                                                          6.67780D-01
```

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"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 8-4-6                                                  13 DEC 1983
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******************** CH. EQ.  *****************
 1.00000D+00  7.04313D+01  2.61901D+03  5.03369D+04  5.72309D+05  2.07271D+06  3.71411D+06  3.80237D+06  1.76729D+06  2.90870D+05
 1.25862D+04 -6.98673D-13
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA         TAU

  -2.03304D+01   2.07386D+01   -4.06609D+01   8.43414D+02   7.00045D-01   2.90416D+01
  -6.66028D-02                                                                          1.50144D+01
  -5.90216D-01                                                                          1.69429D+00
  -8.56801D-01   1.19077D+00   -1.71360D+00   2.15204D+00   5.84056D-01   1.46698D+00
   5.55112D-17                                                                         -1.80144D+16
  -1.26000D+01   1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
  -2.00000D+00                                                                          5.00000D-01
  -2.00000D-01                                                                          5.00000D+00

                         NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
-1.46165D+04  1.13833D+05  4.15215D+05  2.89174D+05  6.82503D+04  1.32721D+04  1.61082D+03
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA         TAU

  -2.51637D-02   2.06414D-01   -5.03273D-02   4.32400D-02   1.21013D-01   2.07942D-01
  -2.00000D-01                                                                          5.00000D+00
  -5.99000D-01                                                                          1.66945D+00
  -2.00000D+00                                                                          5.00000D-01
   1.06373D+01                                                                         -9.40087D-02

******************** Q    /FES *****************
 1.62554D+05  5.35948D+05  5.11782D+05  1.94647D+05  2.96016D+04  1.42320D+03  7.01187D-11
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA         TAU

  -4.92684D-14                                                                          2.02970D+13
  -8.94241D-02                                                                          1.11827D+01
  -2.00000D-01                                                                          5.00000D+00
  -4.08627D-01                                                                          2.44722D+00
  -5.99000D-01                                                                          1.66945D+00
  -2.00000D+00                                                                          5.00000D-01

******************** THET/FES *****************
 1.62554D+05  5.35948D+05  5.11782D+05  1.94647D+05  2.96016D+04  1.42320D+03
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA         TAU

  -8.94241D-02                                                                          1.11827D+01
  -2.00000D-01                                                                          5.00000D+00
  -4.08627D-01                                                                          2.44722D+00
  -5.99000D-01                                                                          1.66945D+00
  -2.00000D+00                                                                          5.00000D-01

******************** NZCG/FES *****************
 1.76775D+03  5.89242D+03  1.46018D+04  2.69228D+04  1.52867D+04  1.97493D+03 -2.26915D+01  8.48033D-12
     REAL          IMAG          -2*Z*W         O**2          ZETA          OMEGA         TAU

  -2.72442D-01   2.23123D+00   -5.44883D-01   5.05263D+00   1.21203D-01   2.24781D+00
  -5.99000D-01                                                                          1.66945D+00
  -2.00000D-01                                                                          5.00000D+00
   3.73717D-13                                                                         -2.67582D+12
  -2.00000D+00                                                                          5.00000D-01
   1.06032D-02                                                                         -9.43110D+01
```

```
"#CBFREQ2"(12/9/83)-PITCH RATE CONFIG 10-1                                                                          13 DEC 1983
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******************** CH. EQ.  *****************
 1.00000D+00  6.83173D+01  2.47442D+03  4.38783D+04  4.42772D+05  4.40589D+05 -2.85687D+04 -2.24894D+04 -8.20802D+03 -1.53661D+03
 0.0          0.0

     REAL           IMAG           -2*Z*W          O**2          ZETA          OMEGA          TAU

 -1.14475D+00                                                                               8.73551D-01
  3.41211D-01                                                                              -2.93074D+00
 -5.68688D-02   2.15231D-01   -1.13738D-01   4.95584D-02   2.55456D-01   2.22617D-01
 -2.10000D+01   2.14243D+01   -4.20000D+01   9.00000D+02   7.00000D-01   3.00000D+01
 -2.00000D-01                                                                               5.00000D+00
 -1.26000D+01   1.68000D+01   -2.52000D+01   4.41000D+02   6.00000D-01   2.10000D+01
  0.0                                                                                       0.0
  0.0                                                                                       0.0

                          NUMERATORS OF TRANSFER FUNCTIONS /FES

******************** ALFA/FES *****************
 5.76307D+03  6.72640D+04  1.62696D+04  3.25064D+03  5.28237D+02  0.0          0.0

     REAL           IMAG           -2*Z*W          O**2          ZETA          OMEGA          TAU

 -1.14288D+01                                                                               8.74983D-02
 -2.13785D-02   1.99105D-01   -4.27571D-02   4.01000D-02   1.06759D-01   2.00250D-01
 -2.00000D-01                                                                               5.00000D+00
  0.0                                                                                       0.0
  0.0                                                                                       0.0

******************** Q    /FES *****************
 6.30323D+04  4.25038D+04  8.22647D+03  4.49398D+02  0.0          0.0          0.0

     REAL           IMAG           -2*Z*W          O**2          ZETA          OMEGA          TAU

 -3.80673D-01                                                                               2.62692D+00
 -2.00000D-01                                                                               5.00000D+00
 -9.36454D-02                                                                               1.06786D+01
  0.0                                                                                       0.0
  0.0                                                                                       0.0
  0.0                                                                                       0.0

******************** THET/FES *****************
 6.30323D+04  4.25038D+04  8.22647D+03  4.49398D+02  0.0          0.0

     REAL           IMAG           -2*Z*W          O**2          ZETA          OMEGA          TAU

 -3.80673D-01                                                                               2.62692D+00
 -2.00000D-01                                                                               5.00000D+00
 -9.36454D-02                                                                               1.06786D+01
  0.0                                                                                       0.0
  0.0                                                                                       0.0

******************** NZCG/FES *****************
-6.97000D+02 -5.11793D+02  3.17284D+03  6.01788D+02 -9.53492D+00  0.0          0.0          0.0

     REAL           IMAG           -2*Z*W          O**2          ZETA          OMEGA          TAU

 -2.44849D+00                                                                               4.08415D-01
  1.89950D+00                                                                              -5.26453D-01
 -2.00000D-01                                                                               5.00000D+00
  1.47067D-02                                                                              -6.79961D+01
  0.0                                                                                       0.0
  0.0                                                                                       0.0
  0.0                                                                                       0.0
```

APPENDIX D

CONFIGURATION TABLE

Configuration No.

KEY: X - X - X - X (Set; Sequence in Set; Model Configuration; Cmd Path Mods, 1 = Wash Out)

PITCH RATE CRITERIA CONFIGURATION TABLE

Note: All configurations X-X-X-1 utilized $1/T_{wo} = 0.2$

$T = \tau_1$ + TIFS Delay + Dynamic Element Delay

CONFIG NO.	MODEL CONFIG	DESCRIPTION	$1/\tau_{\theta_2}$	X'_2	ζ_{sp}	$\omega_{n_{sp}}$	K_c	K_L	K_α	K_q	K_I	$1/T_z$	$1/T_F$	$1/T_{wo}$	τ_1	S1 (T_{wo})	S2 (T_z, T_F)	S3 (K_α)	S4 $(g/V)\phi^2$	T
1-1-1	1	Hi ω_n,	0.38	0.435	0.8	2.79	1.8	4	-	1	2	-	-	-	0	0	0	0	C	0.17
1-2-2	2	Pre-Filter	0.72	0.821	0.8	2.76	1.8	4	-	1	2	-	-	-	0	0	0	0	C	0.17
1-3-7	7	Vary $1/\tau_{\theta_2}$	1.0	1.190	0.8	2.73	1.8	4	-	1	2	-	-	-	0	0	0	0	C	0.17
2-1-1	1	Med. ω_n, no P.F.	0.38	0.500	0.6	1.78	1.8	2	-	1	2	-	-	-	0	0	0	0	C	0.17
2-2-2	2	Vary $1/\tau_{\theta_2}$	0.72	0.931	0.6	1.75	1.8	2	-	1	2	-	-	-	0	0	0	0	C	0.17
3-1-3	3	Neutral Static	0.40	0.25	T_q=0.4		1.8	2	-	1	0	-	-	-	0	0	0	0	0	0.17
3-2-4	4	Vary $1/\tau_{\theta_2}$	0.72	0.25	T_q=0.4		1.8	2	-	1	0	-	-	-	0	0	0	0	0	0.17
4-1-1	1	Hi ω_n + P.F.	0.38	0.435	0.8	2.79	0.4	4	-	1	2	0.435	2	-	0	0	C	0	?	0.17
4-2-2	2	Vary $1/\tau_{\theta_2}$	0.72	0.821	0.8	2.76	0.8	4	-	1	2	0.821	2	-	0	0	C	0	?	0.17
4-3-7	7	Hi τ_{0_2} + P.F.	1.0	1.190	0.8	2.73	1.0	4	-	1	7	1.190	2	-	0	0	C	0	?	0.17
5-1-1	1	Med. ω_n + P.F.	0.38	0.500	0.6	1.78	0.5	2	-	1	2	0.500	2	-	0	0	C	0	?	0.17
5-2-2	2	Vary $1/\tau_{\theta_2}$	0.72	0.931	0.6	1.75	0.9	2	-	1	2	0.931	2	-	0	0	C	0	?	0.17
6-1-1	1	Superaugmented	0.38	0.448	0.46	2.27	1.8	2	-	1	3		-	-	0	0	0	0	C	0.17
6-2-1	1	Superaug. + P.F.	0.38	0.448	0.46	2.27	0.45	2	-	1	3	0.448	3	-	0	0	C	0	?	0.17
6-1-1-1	1	S.A. + W.O.	0.38	0.448	0.46	2.27	1.8	2	-	1	3	-	-	0.2	0	C	0	0	C	0.17
6-2-1-1	1	SA + PF + WO	0.38	0.448	0.46	2.27	0.45	2	-	1	3	0.448	3	0.2	0	C	C	0	?	0.17
7-1-4	4	Conv. Aircraft	0.72	ω_p=0.16 ζ_p=0.01	0.8	2.84	6.0	1	4.5	2.0	0	-	-	-	0	0	0	0	0	0.17
8-1-5	5	SSV (CAL)	0.40	0.586	0.5	1.45	0.7	1.5	-	1	2	0.6	2	-	0	0	C	0	C	0.15
8-2-5	5	SSV (Dryden)	0.40	0.700	0.5	1.09	0.9	1.0	-	1	2	1.0	2	-	0	0	C	0	C	0.17
8-3-5	5	SSV (OFT)	0.40	0.586	0.5	1.45	0.9	1.5	-	1	2	1.5	2	-	0.047	0	C	0	C	0.22
8-4-6	6	SSV (Canard)	0.40	0.590	0.6	1.47	0.9	1.5	-	1	2	0.6	2	-	0	0	C	0	C	0.15
8-5-5	5	SSV (8-1+struct filter)	0.40	0.586	0.5	1.45	0.9	1.5	-	1	2	0.6	2	-	0.035	0	C	0	C	0.28
10-1-1	1	Un - Avg. A/C	0.38	+0.341	0.25	0.22		1	-	1	0	-	-	-	0	0	0	0	0	0.17

APPENDIX E
FLIGHT TEST ENGINEER'S FLIGHT SUMMARY

KEY:

D = Desired

A = Adequate

S = Short

L = Long

SP = Safety Pilot

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	ε	
1	A	729	9/8	1	3-2-4	-	-	All sens. too high	D(L)	D	D	Not included in formal evaluation
2				2		-	-	All sens. decreased, OK	D(L)	D	D	
3				3	5-2-2	-	-	Task seems benign	D(L)	D	D	
4						2	1	-	D	D	D	
5				4	2-1-1	-	-	Slow response	(S)	D	D	
6						6	4	-	D	A( )	D	
7				5	5-1-1	-	-	-	D	D/A	D	
8						4.5	2	Borderline D/A	A(L)	D	D/A	
9				6	1-3-7	-	-	Disturb. too high	A(L)	D	D	
10						5	1	Disturb. Adj, OK. Would like to repeat, couldn't get better than adeq. perf.	A(L)	D	D	
1	A	730	9/9	1	6-1-1	-	-	-	D	D	D	Mod. Turb. on 730
2						3	1	(Mod. Turb.) Good control	D/A(L)	D	D	
3				2	6-2-1	-	-	(T/D 1 Gear)	A(L)	D	A	
4						5	1	Heavy in Pitch, Floating tendency landing more difficult than approach	A(L)	D	D	

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	E	
5	A	730	9/9	3	4-2-2	-	-	Easier to bring down than others (Gen. Comm.)	D	D	D	
6				3		2	1	Good sense of predictability.	D	D	D	
7				4	1-2-2	-	-	(Hard landing ; $\dot{h}$=5.5 ft/s)	D	A/↓	D	
1	A	731	9/9	4	1-2-2	8	4	Sense of over control; couldn't control attitude, sunk near ground tendency to PIO near ground.	A(L)	D	D	Turb. more severe than 730
2				5	3-2-4	3 } 2.5	-	-	A(L)	D	D	
3						2 } 2.5	1	Good predictability; confidence in putting it in touchdown area.	D	D	D	
	B	732	9/12					No evaluations - Dig. Problems				
1	B	733	9/13	1	3-2-4			No TD; Large roll mode T.C.				smooth air; rnwy 10L
2				1					D	D	D	
3				2					D	D	D	
4				2		4*	4*	(Practive) Low lat gearing; good initial pitch response; pushed a little to land.	D	D	D	

* Evaluation Practice

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	ε	
5	B	733	9/13	3	2-1-1	7	3	Pitch overshoot unexpected; Ballooned once; lack of A/S control reflected in PR.	D	A	D	
6				3		5**		Better laterally; good A/S control, would like to see some other time.	D/A(L)	D	D	
7				4	5-1-1	5		Poor $\dot{h}$ control at TD; Adeq. perf. up to that point.	D	A	D	
8				4		4.5***	3	Lack of precise $\dot{h}$ control at flare.	D/A(L)	D	D	
9				5	1-2-2			(No gust input) very sens. in pitch at flare.	A	D	D	
10				5		5.5	4	(Gust in) cautious not to PIO.	D	D	D	
1	B	734	9/9	6	4-2-2			Loosness in pitch; liked it; could put it in desired spot.	D	D	D	Light turb. rnwy 10L
2						3	1	Liked it; loosness gone.				
3				1	4-1-1			No TD-Pitch dwn input; fast	-	-	-	
4								Look at it again	D	A	D	
5						5	1	Lack of flt. path control	D	A	D	

* Evaluation Practice ** Rated overall Evaluation at 7 *** Final rating

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	ε	
6	B	734	9/13	2	1-1-1			No TD-sank in close (PIO?)	-	-	-	
7						7	3	Unpred. TD pt; would like to see some other time.	D(L)	A	D	
8				3	3-1-3			No rapid overshoot	D/A(L)			
9						6	3	Poor $\dot{h}$ control in close	D	D	D	
10				4	3-2-5			Pitch PIO	D	A	D	High K_c no jabber filter
11						9	4	No TD - Pitch PIO	-	-	-	
1	A	735		1	7-1-4			Harder TD than expected	D	D	D	
2						3	1	Little heavy in pitch, but accurate; good pred. good A/D control.	D	D	D	
3				2	2-2-2			-	D	D	D	
4						4.5	2	Final response a little unpredictable.	D	D	D	
5				3	1-1-1			-	D	A	D	
6						5	2	Sacrificed $\dot{h}$ control for Touchdown control; landing slightly off.	D	A	D	

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	$\mathcal{E}$	
7	A	735	9/13	4	4-1-1			-	D	D	D	
8						2.5	1	Good A/C; Final response predictable.	D	D	D	
1	B	736	9/14	1	2-2-2	3		Unaware of $\dot{h}$ mag.	D	A	D	Mild turb.
2						3	2 (SP-5)	Slight tend. to PIO; liked it; tried to control $\dot{h}$; (SP - PIO TD tendency)	A(L)	D	D	
3				2	5-2-2			-	D	D	D	
4						3	1	Good pred; no PIO tend.	D	D	D	
5				3	1-3-7			Pushed over to get on gnd.	D	A	D	
6						7	4	No EP TD; flare crit. on both approaches	A(L)	D	D	
7				4	6-1-1			No TD, flap rate	-	-	-	MODEL NOT VALID
8								Bad A/S control	D	D	D	
9						6	3	Tendency to PIO due to pitch response.	D	D	D	
10				5	6-2-1			Heaviness in forces	D/A(L)	D	D	
11								(K_C=2.7) forces better; repeat.	D	D	D	
12						2	1	Good flaps; $\dot{h}$ control; good pitch resp. pred. good	D	D	D	

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	ε	
1	A	737	9/14	1	6-1-1			(K_C = 1.8)	A(L)	D	D	No digital recording on this flt.
2								Look at it again	D	A	D	
3						5	2	Sloppy $\dot{h}$ control near ground; landing more diff. than approach	D	A	D	
4				2	6-2-1			Long touchdown	A(L)	D	D	
5						4	1	Had to work at landing predictable; OL control excellent.	D	D	D	
6				3	8-1-5			Abort - sens. problems	-	-	-	
7								Abort - sens. problems	-	-	-	
8					8-2-5			Abort - cmd gain problem	-	-	-	
9				4	1-2-2			Floated	A(L)	A	D	
10						7	2	Floated; no osc. motions; couldn't get desired resp.	A(L)	D	D	
11				5	1-3-7			Doesn't want to flare.	D	A	D	
12						4	1	Landing a little diff; solid pitch response.	A(L)	D	D	

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	ε
13	A	737	9/14	6	3-1-3			Tendency to balloon; flt. path PIO tendency.	D(L)	D	D
14						5.5	3	Slow sluggish aircraft.	D	D	D
1	B	738	9/14	1	7-1-4	3		Liked it.	D	D	D
2						2.5	1	Good predictability.	D	D	D
3				2	8-1-5			Felt as if undesirable motions would have occurred.	D	D	D
4						4*	2	No TD possible undesire-able motions.	-	-	-
5				4	3-2-4			-	A(L)	D	D
6						5	1	Floating tend; pitch pred. good, although sluggish; TD control a problem.	D(L)	D	D
7				5	2-1-1			Slow; high nose attitude	D(S)	A	A
8						7	3	Poor TD, A/S control.	A(L)	D	D
1	B	739	9/15	5	6-1-1			Felt PIO coming on.	A(S)	D	D
2								Repeat; good $\dot{h}$ ctrl, bad TD prec; slow int'l resp	D	D	D
3						6	4	Osc. tend; poor A/S perf.	D(L)	D	D

* Evaluation Inadequate

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	ε	
4	B	739	9/15	6	6-1-1-1			Did not feel oscillatory; Bad A/S control	D	D	D	
5						A/S 3(4)	1	Good flare, TD Control	D	D	D	
6				7	6-2-1-1			No osc. tend; good pred.	D	D	D	
7						3	1	No PIO tendency	D	D	D	
8				8	4-3-7			Floated	UNDES(L)	D	D	
9						7	1	Floated; Lack of prec. No $\dot{h}$ problem,	A(L)	D	D	
1	A	740	9/15	1	8-3-5			Excellent approach	D	D	D	No Dig. Rec.
2						5	3	App perf. OK; Tend. to float; (late gust) (SP take-over at TD → overrot.)	D	D	D	
3				2	8-2-5			Gust bothersome - overrot.	D	A	D	reduced K_c, stick thru jabber filter on shuttle configs.
4						8	4	Damped PIO; App perf. OK; Had to suppress landing oscillation.	A	A	D	
5				3	8-5-5			Floated	A(L)	A	D	
6								No TD - Flap rate	-	-	-	
7						5	3	Poor pred. in close; No PIO, but ballooned.	D(S)	D	D	

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	ε	
8	A	740	9/15	4	8-1-5				D	D	D	
9						4	1	(Late Gust) Good app perf; Solid feeling in control.	D(L)	A	D	
1	B	741	9/19	1RL	8-1-5			Abort TD - Bad xwind corr.				
2				1				Abort TD dump				
3				1				Hard TD not controlled.	(L)D	D	D	$K_c = 3.53$
4				1LR		6	1	Prob. ctrl. γ, $\dot{h}$ in flare	D	D	D	
5				2RL	8-2-5			PIO	D	A	D	Movie
6				2LR		7	4	In, resp. slugg; diff TD prec; floated.	(L)D/A	D	D	Movie
7				3RL	8-3-5			No PIO progression	D	A	D	Movie
8				3LR		7	3	No TD - Too slow; didn't PIO as much as prev. config.	-	-	-	Movie
9				4RL	3-2-4			Tendency to float in flare	D	D	D	Movie
10				4LR		4	1	Had to push to get on gnd.	D(L)	D	D	Movie
11				5RL	4-1-1			Large power changes; start of PIO.	D	D	D	
12				5LR		6	3	No pitch PIO	D	D	D	Movie

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS	TD	$\dot{h}$	ℓ	
1	A	742	9/20	1	8-1-5			No TD (practice)	-	-	-	Turbulence
2				1					D	D	D	
3				1		5.5	2	Tend. to float at flare; Not pred. in close.	D	A	D	Movie
4				2	8-3-5			No TD - $\dot{h}$; PIO tend; osc.	-	-	-	
5				2		8	4	Unpred final resp; Low freq. γ PIO.	D(L)	D	D	Movie
6				3	8-5-5				D(L)	A	D	Movie
7				3		7	4	Poor A/S control; tendency to float, overcontrol.	U(L)	D	D	Movie
8				4	8-2-5				A(L)	A	D	Movie
9				4		8	4	(No TD) Tend. to PIO; A/S control near gnd. sacri-ficed for γ, $\dot{h}$ control.	-	-	-	Movie
1	A	743	9/22	1	8-3-5-1			D TD				
2				1		3	1					
3				2	8-4-5			D TD				
4				2		1	1					

APP	PILOT	FLT	DATE	EVAL CONFIG	MATRIX CONFIG	C-H RATING	PIO RATING	PILOT COMMENTS TD $\dot{h}$ E
5	A	743	9/22	3	8-1-5-1			D TD
6				3		2	1	
7				4	4-3-7-1			A TD
8				4		4	1	
1	A	744	9/23	1	8-5-5-1			D TD Movie
2						4	2	
3				2	8-3-5			D TD Movie
4				2		7	3	
5				3	8-3-5-1			A TD Movie
6				3		3	1.5	
7				4	8-2-5-1			D TD 1st approach - float
8				4		7	4	2nd approach - too low in close Movie

APPENDIX F

PILOT COMMENT TRANSCRIPTS

FLIGHT 729	CONFIGURATION: 5-2-2	PILOT: A
DATE: 9/8/83	HQ RATING: 2	PIO RATING: 1

PILOT: First Evaluation - So I think it was clearly controllable and I could do the job, no problem there, I found the aircraft satisfactory without improvement for what I saw so I will say that I could achieve desired performance and do the task. I will comment that the task is fairly benign in the sense that the disturbance in close doesn't really bother me so I think for that job I could do it with pilot compensation not being a factor so I would give it a 2.

The Feel - We made some changes and I have no complaints there.

Roll and Pitch Sensitivity were fairly satisfactory.

Initial Response was good.

The airplane was predictable.

Pitch roll harmony was good.

No special techniques except I learned to get on down the road after we got down towards the runway more than I did the other day so I could get down in flare and not run out of airspeed.

No tendency to PIO. The airspeed control with the throttle was good, it uniformly decreased the throttle with the feeling of control.

Performance - flight path corrections were easy - airspeed control good.

Touchdown - I didn't have any problems - no crosswinds - no tendency to float it landed when I wanted it to. Neither the approach nor the landing was very difficult no effects of turbulence, crosswinds.

Good features - I felt I had positive control in learning the task and the airplane is coming together to some extent so I think I will stick with my rating of a 2. The PIO rating had no undesirable motions so I give it a 1.

BERTHE: So on that last comments was for Configuration Smith-3 on Flight 729.

FLIGHT 729	CONFIGURATION: 2-1-1	PILOT: A
DATE: 9/8/83	HQ RATING: 6	PIO RATING: 4

The rating - I think it is controllable, I think I could achieve adequate performance, barely, not in sink rate.

BERTHE: No we got the first touchdown was short which was not adequate and the second time was a high sink rate.

HARPER: The pitch down location was desired.

PILOT: I'm going to say that I could just barely get the job done for now anyway and say that its not satisfactory without improvement. I could not achieve desired performance so it's either a 5 or 6 considering I landed short the first time with a good sink and the right place with a high sink rate the second time - I'm going to say that it's a 6 because I didn't feel like I was working the controls hard but I was not achieving the performance for reasons that I don't know that I can separate out.

I dont have any comments on the feel - it seemed to me that the airplane was not responding fast enough to my inputs so my predictability of the final response was a problem to me, I was obviously misjudging that.

Pitch roll harmony - no comments there - no special inputs that I noticed. I noticed the tendency to overcontrol in some undesirable motions in response to the disturbance. In fact I don't really feel the disturbance discretely as much as I felt like suddenly I was overcontrolling so.

Sensitivity - OK.

Airspeed control - no comments there.

Flight path correction - I could make them far out OK. but not in close. Problems in judging the sink rate were evident I didn't use any unusual control techniques like we should have. Landing was clearly more difficult than approach.

Turbulence - I didn't notice any external stuff. The gust did bother me in close in the sense that it set up two or three oscillations to get it sorted away.

Good features - I don't have any comments there.

The problems I have already outlined.

The rating for now - I think I could get it down on the ground in one piece so I will say at this moment that I could just barely achieve adequate performance and give it a 6.

If I attempt tight control I did cause oscillation. I would say they were not divergent and I would give it a 4, for the PIO rating.

End of comments - voice recorder OFF.

However the predictability was reasonable.

FLIGHT 729	CONFIGURATION: 5-1-1	PILOT: A
DATE: 9/8/83	HQ RATING: $4\frac{1}{2}$	PIO RATING: 2

The feel I noticed the initial forces in pitch were a little on the heavy side. No problems with the displacement, the initial response in pitch I thought was a little slow and the final response. However, I had no tendency to overcontrol that I noticed.

Pitch roll harmony - no complaints there.

No special inputs - no tendency to PIO.

Sensitivity in pitch - felt a little on the heavy side but maybe if I had my druthers I would like it a little more sensitive but I don't think that's a big problem.

Speed control - was OK.

The approach performance - was a little ratty on the glideslope I think that the airplane was generally a little bit slow in pitch.

Airspeed control - seemed O.K.

Problems - I was pre-occupied with the last one trying to worry about if I landed, which I think I did, on the first one in a bit of a crab trying to worry about the crosswind so that I managed to screw up the touchdown zone a bit. I think you could get the airplane down where you wanted it I didn't notice any tendency to float, although I do note that with these airplanes that when I get near the touchdown and I am low I am pushing forward a little bit to get it down and not being concerned about doing that.

Approach and landing - I think the landing was more difficult although the approach, glideslope tracking was a little worse than I have seen.

Crosswind - affected me in the sense that I was trying to do something about it but did not adequately do anything about it and we landed in a little bit of a crab on the first one, the second one we got a little bit off center.

Summary comments - nothing further to add.

Pilot rating - I think it is controllable, I think I can get adequate performance not satisfactory - I will say it was less predictable than I desired and

I debate between desired and adequate and since Bob Harper did it once I will do it, I will give it a $4\frac{1}{2}$.

PIO rating - Tight control - did it cause oscillations - no. Undesirable motions - sometimes I think I was not getting the control that I wanted and I will express that by saying that it's a 2. They were both adequate (Berthe).

FLIGHT 729	CONFIGURATION: 1-3-7	PILOT: A
DATE: 9/8/83	HQ RATING: 3	PIO RATING: 1

OK on both of those - the first one I missed the touchdown zone partially because of the gusts - the second one I really can't put it down to the pitch characteristics that I missed it. I just didn't get the throttle organized in my view. In terms of the ratings - in terms of the pitch control I felt it was controllable I could achieve adequate performance and I really felt that it was satisfactory. So I'm going to say that and I'm going to comment on what I actually did but in terms of the pitch response I thought I could control and it was a question of getting down early enough and I think I do better, maybe I was cheating a little bit, I don't think so but I do better when I hit an altitude at the road rather than watching the glide path. The glide path has some wrinkles at the end and I go chasing those and I get all screwed up. OK, I like the airplane in general so I think I'm going to say that I could achieve desired performance if I had to do it a couple of more times. Anyway it is satisfactory to me in terms of the pitch response, so I would give it a 3 on that basis. Let me talk some more about it.

The feel forces displacements were good - harmony no problem.

Roll and pitch sensitivity is good.

Initial response - was excellent. Very predictable and quite on the quick side but not overly so.

Pitch roll harmony - was good.

Special inputs - I didn't have any.

No tendency to PIO.

Sensitivity was good.

Airspeed control was satisfactory.

Glideslope performance was good.

Flight path corrections - I think it is a question of technique in getting on down hill early enough. Maybe I was making the side step a little later but I did not. The first one I had a little higher gust but I really couldn't get

down and the second one I just felt like I had very positive control and this is likely a candidate to fly again some time because of what I am saying, I did land long but I felt like I was in good shape - good control so I would move my aimpoint just slightly for this one and I think I can do the job. No problem with the flare except that I did go on by it. I will have to say that I changed the ________ came back didn't feel like it was a floating tendency again because I felt like I just didn't have the right aim point but we will look upon that again I guess some time.

Approach and landing - no distinction there, no problems. We did have a crosswind slightly to the left I guess but it didn't amount to anything although I tried to think about it but I didn't have to. The gust input was large on the first one and noticeable but not a significant problem on the second approach.

The good features - I really felt the pitch control was responsive and predictable.

HARPER: Do you want to give me the ________

PILOT: The overall rating I will just review it again.

It is certainly controllable. Is adequate performance attainable - well I'm going against the grain a little bit - I think it is. If I had to fly three or four approaches I think I could do it but I may be fooling myself there but anyway I'm going to stick with what I have said. Its a 3.

FLIGHT 730	CONFIGURATION: 6-1-1	PILOT: A
DATE: 9/9/83	HQ RATING: 3	PIO RATING: 1

PILOT: First evaluation - Just some general comments still am getting organized getting down and I have just a feeling that I am too high which is what we are trying to do is make you work at it so I still have to organize myself and get a little more active on the controls to get down to be a little more comfortable on hitting the spot, but I managed to catch the tail end of it. So I think it was controllable - I could achieve desired performance. Is it satisfactory without improvement - I am not sure about that at this point so let me - I am debating a 3 and 4. So let me make some comments and we will talk about the specific rating at the end.

The feel - no comments there. Sensitivity displacements were, forces displacements were satisfactory.

Initial response - was good.

Predictability of the final response - seemed to be reasonable. I had a little tendency to float, having to push forward to get on the ground, that's a little uncomfortable although I didn't have any apprehension about doing it.

No tendency to PIO. Airspeed control was satisfactory. No problem intercepting, well we didn't have the glideslope, but controlling the flight path and the airspeed on approach.

Flare and touchdown - a little tendency to float which required getting down on in a continuous fashion with the stick so I start to flare then I have to ease off. The airplane would float and I would slowly push forward with I think I could do but it's unnatural for me but I was a little apprehensive about doing it.

The approach and landing - no great distinction there. We do have a crosswind but we are taking it out. Turbulence didn't bother me nor did minor gusts.

Good feeling - I did have a good feeling of predictability about the airplane although I had to as I said ease it onto the ground by some forward pressure on the stick, but overall I think I had good control and reviewing it in the rating I certainly can do the job and I think I can achieve desired performance. I would say it was satisfactory without improvement, mildly unpleasant deficiencies would qualify, I would like to use my learning technique to land I guess and so I would give it a 3 rating.

The PIO rating - nothing there, I would give it a 1.

FLIGHT 730	CONFIGURATION: 6-2-1	PILOT: A
DATE: 9/9/83	HQ RATING: 5	PIO RATING: 1

PILOT: OK, some comments on the second configuration. It is certainly controllable I can get the job done in terms of adequate performance, I could not achieve desired performance. I could get the airplane down in terms of hitting the ground in good order but I couldn't get it down where I wanted it so I think I have deficiencies that warrant improvement and I would right now rate it a 5, cause I could only achieve adequate performance.

The feel - nothing in the roll that bothered me. I did have a sense that the airplane was heavy in pitch and that's just something that I noticed.

The initial response seemed alright and the predictability, it just seemed a bit on the sluggish side to me. The principle problem was down close to the ground I just couldn't get it to smoothly continue on, control the sink rate near the ground, I overshot both times and floated.

No tendency to overcontrol. The sensitivity in the pitch gearing I don't have anything that I would identify with that, that I would change, that I think would improve things.

Airspeed control - a little bit shabby near the end I was trying to compensate a little bit for going down hill. I didn't speed up going down hill but I had a little feeling of imprecision in the flight path control consistent with not getting down where I wanted. The problem was tendency to float - no tendency to overcontrol I just could not get it organized to get down on the ground. So the landing was more difficult than the approach. Crosswind was there a little bit but it wasn't a factor in affecting my pitch control. The problem is a tendency to float no tendency to overcontrol no feeling of that I was going to have a problem in terms of managing pitch attitude but just couldn't get it down where I wanted so I am going to stick with the rating that I gave it. I only achieved adequate performance but I don't think it was any worse than a 5, so it's a 5 rating.

PIO rating scale - I would give it no undesirable motions so I would like to give it a 2 but I don't see any reason why it shouldn't be a 1 so it's a one.

FLIGHT 730	CONFIGURATION: 4-2-2	PILOT: A
DATE: 9/9/83	HQ RATING: 2	PIO RATING: 1

PILOT: It's controllable. I certainly could do the job. Adequate performance is attainable. It's satisfactory without improvement. I think it has no deficiencies. It's a 2.

No complaints on the forces - displacements - harmony was good. Pitch and roll sensitivity well matched. The pitch was responsive and predictable. I tended to find myself flying with little pulses down in close cause I could move the nose and stop it quite rapidly. Especially on the first approach I found myself jerking the stick a little bit. But I had good control and that is what I was commenting. I had very easy control in the sense of getting on down from the initial condition of the offset. It just seemed like the whole approach, I had good sense of predictability in the flight path control and that really then makes you come out and be able to hit the touchdown zone and perform the task satisfactorily. So the flare and touchdown there was no problem, no tendency to float I could put the airplane down and land it when I wanted and I think I could control the sink rate as desired.

Approach and landing were both good - turbulence, crosswinds not a factor.

Good features - solid, quick control in pitch and I would not change the rating so it's a 2, and the PIO tendency was not there so I would give it a 1.

FLIGHT 731	CONFIGURATION: 1-2-2	PILOT: A
DATE: 9/9/83	HQ RATING: 8	PIO RATING: 4

PILOT: Just some general comments - you have more turbulence in crosswind although we have taken out most of the crosswind so those are all my excuses.

The airplane is controllable - I cannot achieve adequate performance I just cannot get precise near the ground and I have a sense of overcontrolling and small PIO although I don't see big attitudes but that may be a function of my visual scene out here, I just have the visual sense that I am overcontrolling and am in a PIO, at least the first part of one. Can't be precise so that I think it has major deficiencies and I would debate whether it is a 7 or an 8 so that I think I will give it an 8 for the moment and then I will give my comments here.

The feel - I have nothing that stands out there in terms of forces or displacements.

The pitch - the initial respone does not come through to me as being anything of a problem. The predictability of the final response down in close to the ground is a problem and it was not predictable I could not control the attitude in the sink rate close to the ground. I think I had a higher lateral task a little bobbling around in response to the gusts but I really feel that wasn't the cause of my problems.

Tendency to PIO near the ground - yes didn't seem to diverge or I wasn't apprehensive about it but I did overcontrol.

Airspeed control - I didn't notice anything special there.

Flight path corrections close to the ground - were difficult to make in an orderly fashion.

Airspeed control - I don't remember much about that.

The problems in the flare were a matter of controlling the sink rate. I did in the course of trying to contend with the pitch go right on by the landing area, and so I tended to float because I couldn't get things under control I guess.

Landing - was more difficult.

Turbulence was a bit of a factor that the pitch job took away some of my ability or workload capability in pitch, in an airplane where I needed most of it.

The problems - were lack of precision in pitch control near the ground and bleeding over into control of sink rate. I couldn't get it on the ground in the area where I wanted to achieve adequate performance. So I'll stick with a rating of 8, because I think control was a question right near the ground. When I entered the loop tightly near the ground divergent oscillations - no. It does cause oscillation yes. Not divergent - a 4 for the PIO rating.

FLIGHT 731	CONFIGURATION: 3-2-4	PILOT: A
DATE: 9/9/83	HQ RATING: $2\frac{1}{2}$	PIO RATING: 1

PILOT: Two approaches interrupted by some other problems and the last one was really good, the first one was a good touchdown, not quite as precise as the last one so I did a very good job on the second one.

Controllable - I could achieve desired performance so I would rate my first one a 3 and the second one a 2 so I fudge it just slightly and give a $2\frac{1}{2}$ for now.

The wheel forces in doing the task and so on were just fine if I fly up-and-away and maneuver rapidly I think they are a little bit heavy but as I fly the airplane as we are doing the task I didn't notice it at all.

The harmony was good.

The initial response - was OK.

Predictability - was outstanding on the last one and satisfactory on the first one.

Pitch roll harmony - was good.

No tendency to PIO.

Sensitivity was satisfactory.

Airspeed control good.

Flight path corrections were outstanding on the last one an OK on the first one.

Flare and touchdown - I didn't really - I had to put the airplane on the ground in other words I can't just smoothly come through with the stick and come aft and throttle off and come on down it kind of stops there and I just have to ease it a little bit or stop pulling back. It was comfortable doing that I didn't have any apprehension about pushing forward or actually stopping pulling back. A little bit of technique than I am used to in standard airplanes. However, you could do it with good precision.

Approach and landing - were equal goodness.

Turbulence - we got some today as we mentioned, didn't really become a factor especially on that last one - crosswind when we take it out, no problem.

Good features - good confidence in being able to put the airplane on the ground. I am much better I think in projecting my trajectory going from right to left than left to right. I always feel more ahead of it when I am coming from the right to the left, it's fairly natural I guess.

The rating I think on the basis of what I saw - I think I'll stick with what I said with $2\frac{1}{2}$.

No oscillations caused - no undesirable motions. I would give it a 1 on the PIO scale.

FLIGHT 734	CONFIGURATION: 4-2-2	PILOT: B
DATE: 9/13/83	HQ RATING: 3	PIO RATING: 1

PILOT: It seemed like there was some looseness in pitch, that is, I was stirring the column around hunting for an input to move the nose where I wanted it to go but I liked the configuration reasonably well I thought I could make the airplane go pretty much where I wanted it to go it's just that it took a little iterative dithering with the stick at first to get it moving in the right direction but I thought the amount of control I had was relatively good after I sorted that out shortly after making that high dip and felt I could put it pretty much where I wanted it, to put it on the runway.

I liked that configuration I don't really think there was an excessive amount of looseness in pitch, I could put the airplane pretty much where I wanted it to go and I did notice a little bit of a tendency to stay fast in the middle of the approach but in general I liked it and I'd give that a 3.

BERTHE: Any PIO rating on it?

PILOT: No, I didn't really get any undesirable motions out of it. Well, if we rated it I guess we would give it a 1.

FLIGHT 734	CONFIGURATION: 4-1-1	PILOT: B
DATE: 9/13/83	HQ RATING: 5	PIO RATING: 1

PILOT: I noticed the lack of ability to control the flight path angle very precisely, I'd be a little bit high and in fairly close I'd get low and then flatten out and fly along not knowing if I was really going to be able to put it down where I wanted to touchdown the runway or not so the primary impression was one of not having as good a control of flight path angle as I like. I notice that for pitch changes it didn't overshoot on the first configuration. Closed loop tried to move to a new pitch attitude, hold it there was a half a cycle overshoot, didn't have it this time but again the main problem was trying to predict and to control glide path angle. I noticed in making speed changes in this configuration it seemed as if I had to hold pressure on the column longer to affect the attitude change which would give me a speed change that I had with some of the other configurations I had to hold pressure on the stick longer to make those changes.

I would give that a 5 on the Cooper-Harper scale and PIO rating even though I got into a lateral one there. I didn't have any problem with pitch and I will make that a 1 on the PIO scale.

FLIGHT 734	CONFIGURATION: 4-1-1	PILOT: B
DATE: 9/13/83	HQ RATING: 7	PIO RATING: 3

PILOT: First one sank in close and had to put in a nose up input of pretty big magnitude to disconnect it. I wasn't disconnected so soon, I don't know if it would have become a PIO or not, at least it was an undesirable motion of the airplane that I was trying to correct for. How oscillatory it would have been I don't know, I guess you do.

At any rate the first one I would have to lean toward a 7 there because I wasn't able to make a touchdown. On the second one I felt that it was sort of unpredictable about where I was going to land and I left the power on a little bit too long and I ended up floating, kind of leveled over the runway kind of landed long and I couldn't really tell what to do to make it go where I wanted to go on the end of touchdown for lack of predictability there. So based -the first one the fact that we disconnected for safety reasons I don't really know what happened had we gone any further is going to make me weight this in favor of a 6 rather than a 7 because I'm not sure had I gone longer whether I would have been able to touchdown in the touchdown zone without being oscillatory or not.

FLIGHT 734	CONFIGURATION: 3-1-3	PILOT: B
DATE: 9/13/83	HQ RATING: 6	PIO RATING: 3

PILOT: On this configuration the impression I get is that it's not so much it doesn't overshoot in a very rapid manner. I will make a pitch input pitch attitude and it looks like it's going where I want to go and then it will gradually creep up as if there is a real low pitch rate after I think that I have stopped it and it will creep from where I wanted it to be. On that configuration it felt like I had relatively poor h control when I got down close to the flare and hence flight path control in close was bad, I didn't have a PIO tendency but I get down, I get flat and level off and fly along for some period of time I couldn't quite modulate, I couldn't modulate the h to make it land where I wanted it to, it may have something to do with this apparent error that builds up after I think I have made an input, gotten it about where I want it then it tends to drift away, it's a nose up input it tends to drift further nose up. Or vice-versa.

Pilot rating - You have a rating of 6.

FLIGHT 735	CONFIGURATION: 7-1-4	PILOT: A
DATE: 9/13/83	HQ RATING: 3	PIO RATING: 1

PILOT: Just a quick run through the rating scale. I think it's controllable -I could achieve adequate performance in fact I could have achieved desired performance so I think it's satisfactory without improvement. I did think it was a little heavy in pitch. I couldn't be really continuous with the control near the end, I had to pulse it but I felt like I could be accurate with it, so I would give it a 3.

The feel forces - I noticed right from the time that I got the airplane it seemed to have a nose down out of trim and throughout the coming around the corner I was having to trim aft, so the forces felt just a little on the heavy side.

Displacements I didn't notice.

Harmony was not great, I guess because I noticed the pitch.

Initial and final response - I have no complaints about.

Special pilot inputs - I tended to pulse the airplane to get the curvature in the flight path that I wanted but I could do it with good predictability.

Airspeed control was good.

Flight path corrections - were predictable. No problems with the flare.

Touchdown - on the first one a little harder than I would have liked but within desired parameters. The second one was better.

Approach and landing - nothing really to choose there.

No turbulence, noted we did not have a gust on the second approach but I don't think that's an eliminating problem.

Good features - it was positive, slightly on the heavy side but predictable.

Rating - I would stick with a 3. The difference from being without complaint would be the pitch forces.

PIO tendency - I didn't see any so it was a 1.

FLIGHT 735	CONFIGURATION: 2-2-2	PILOT: A
DATE: 9/13/83	HQ RATING: $4\frac{1}{2}$	PIO RATING: 2

PILOT: Second configuration - it's controllable I could achieve adequate performance and I did in fact achieve desired performance but I wasn't entirely happy with it so right now I am going to say it's satisfactory without improvement because I really was kind of flying open loop near the end I had just a touch of apprehension about the airplane but I can't totally explain but I really couldn't get the touchdowns. I could get the position pretty well organized but the sink rate was not good. I couldn't be continuous and hit the spot as well as the sink rate so I right now I am thinking of a 4 or 5 and I will review it again.

The feel - I didn't notice anything there - the force or displacements.

Initial response - it seemed satisfactory. I had a feeling that the final response was just a little on the unpredictable side it tended to float up.

Special pilot inputs - I don't have anything that I could describe.

Airspeed control was OK.

Glideslope flight path corrections were OK right until the very end when the last correction I would never make it quite right and would hit a little harder than I expected or wanted to. So the touchdown precision was not quite up to the mark.

Unusual motions - none.

Techniques - I tended to not want to get involved with the control in close so I think that resulted in some harder not real touchdowns but harder than I wanted.

The landing was more difficult - crosswinds turbulence were not a factor.

Reviewing the rating then I am going to say that I could have achieved desired performance and it's somewhere between a 4 and a 5 so I will just give it a $4\frac{1}{2}$ to express that.

PIO rating - I didn't see any oscillations I did see some desirable motions in the sense that I didn't get the response that I wanted to I will just reflect by saying that I give it a 2.

FLIGHT 735	CONFIGURATION: 1-1-1	PILOT: A
DATE: 9/13/83	HQ RATING: 5	PIO RATING: 2

PILOT: It's the comments to the third configuration. It kind of reminded me of the last one a little bit in some ways.

It's controllable - I think I could achieve adequate performance and I could hit it in the desired area but I don't think I could do it the way I wanted. So I don't think my touchdowns were desired although maybe they were borderline on the 3 ft/sec but I really am sacrificing the sink rate for getting the desired touchdown zone because I really am not really controlling it as well as I would like so I will be dealing with the same kind of ratings 4 or 5. So I will make some comments and then review it.

Forces displacements - nothing noticed there.

No comments on the sensitivities.

The initial response - I don't have anything to say there. I did feel on the first approach that I had a sort of a high frequency tendency to overcontrol very subtle, I just had a little feeling of apprehension which I didn't really see much of a problem but I think that is what made me back out of it just a little bit at the end and that resulted in higher sink rate than I think I should achieve but in any event - Airspeed was OK.

Flight path corrections could be done - no problem initiating the flare.

Touchdown - I just hit a little harder than I wanted whether that is technique or the airplane I don't know so I have already said what I wanted to say about that.

The landing was slightly more difficult - no effects of turbulence I did notice the gusts that time that upset my trajectory. Nothing really bad with the airplane but I didn't really feel that it was as good as the ones I have seen where I am able to coordinate better. So I think it is satisfactory, I got desired performance in terms of touchdown but not in terms of, well it's borderline on sink rate so I am going to say it's a 5 on that basis.

The PIO rating - is not so much undesirable motions tend to occur I don't think the task was compromised I just had a feeling that I was going to not get quite the response that I wanted so I will give it a 2 to reflect that.

FLIGHT 735	CONFIGURATION: 4-1-1	PILOT: A
DATE: 9/13/83	HQ RATING: $2\frac{1}{2}$	PIO RATING: 1

PILOT: Comments for the fourth and final configuration. It's controllable, I could achieve accurate performance and I did in fact achieve desired performance. I could get the airplane down where I wanted, I just felt that I had to pulse the airplane a little bit, in fact all of them seem to be that way but I'm making little pulses to kind of jab the flight path around. The airplane felt pretty solid and I would have to say that _________. Right now I would give it a 2, I will have to think about that a little more.

The forces displacements - harmony - no problem.

Initial response - seemed adequate, satisfactory.

Final response - seemed predictable. Harmony was not a problem.

The only special techniques - I tended to be pulsing the stick back and forth in a random fashion trying to curb the flight path, it's not a continuous motion. So the approach performance flight path corrections could be made with good precision.

Flare and touchdown - the problems with the flare and touchdown, I just don't think I have the kind of control over the sink rate right near the end that I have seen although the last touchdown I thought was pretty good. I had a little bit nose up attitude, it felt a little bit more like I was landing the airplane and not going for the deck at the last second to try and hit the spot.

Approach and landing - no distinction there. We did have the first landing a little bit of a residual crosswind I did not get out of there and we landed with a slight crab which jolted the whole airplane a little more than just the sink rate.

Good features - I could get the job done, I really think I have seen better airplanes in my travels so far. I think it was a good airplane, could achieve the desired performance. It's certainly satisfactory without improvement. I'm just going to give it a $2\frac{1}{2}$ on the basis that I think I have done better with some others. So it's a $2\frac{1}{2}$ that I would give on the rating I don't think I saw any undesirable motions so I would give it a 1 on the PIO scale.

FLIGHT 736	CONFIGURATION: 2-2-2	PILOT: B
DATE: 9/14/83	HQ RATING: 3	PIO RATING: 2

PILOT: Comments on first configuration. The pitch response to a step is damped but takes a number of column iterations to make a pitch pull to a particular point and it's rather sloppy in that respect.

I was conscious on that run of not being aware the sink rate was the size it was, sorry about that.

BERTHE: I think we hit a little bit sideways, that was part of it.

PILOT: As far as feel the displacements forces, harmony OK.

Response to the input - initial response was a little slow and there was little difficulty and predictability of the final response but not excessive.

No special pilot input.

Slight tendency to PIO.

Airspeed control OK.

Performance - I have forgotten what the gouge is it the cable, the cable I guess is the minimum part minimum end of the touchdown.

With the flare - I didn't perceive that I was going to touch down hard until we touched down. I didn't have excessive problem with that except for the fact that my perception wasn't good. Crosswinds may have had some influence on the touchdown rate. For the scale - it is controllable, performance was adequate. I'm going to make some comments now so I can go back and compare them to the second run. It is satisfactory without improvement and give it a 3 and I'll compare that to the next run and then give it an overall configuration rating.

Run 2 Configuration 1: This configuration appears to have Phi square term in it that helps around the turn I don't know if it does or not but I don't have to pull on it to get it around the turn. There's no tendency to have to push it down to continue around the turn inspite of the fact that I didn't have to pull into the turn it seems to be a pretty good mixture not having to pull. I leveled out and was flying into the touchdown zone and landed a little bit

long. Only a very slight tendency to PIO. I had to hunt for the ground but I think that was due to my recalibrating depth perception. I felt like the configuration was generally pretty controllable.

Same comments in general on the feel response. Again a slight tendency to PIO.

The flare and touchdown again, trying to get the h I ended up leveling off, I liked the configuration inspite of that. I think some of it's due to my depth perception trying to avoid landing long. Touchdown point a little long. Other factors OK.

Going back through the handling qualities scale again.

I think it's satisfactory without improvement. The fact that I seem to be not able to quite get the final h control right I am going to attribute it partly to the airplane and partly to me and I'm going to call that a 3.

The PIO scale - there are some very slight undesirable motions and I'm going to and as I dither with the stick trying to get it to stabilize and get it where I want it and I'm going to call that a 2.

BERTHE: Comment is I think you are blaming yourself when I think you should be blaming the airplane. And here is a case where you got adequate performance but you called it a desired airplane. Just pointing that out.

PILOT: I will think that over. First touchdown was hard but the position was OK, is that correct? The second was easy but it was long - well I will keep that in mind and re-think that after this next configuration.

FLIGHT 736	CONFIGURATION: 5-2-2	PILOT: B
DATE: 9/14/83	HQ RATING: 3	PIO RATING: 1

PILOT: This is the second configuration flight 736. I handled her fast I'm showing a 153 - OK instrument power is back on, we are slow.

On the third one of the second configuration of the day you had a tendency to get a little low in the middle and stay low in close, the tochdown sink rate lineup appeared to be OK.

On this configuration I'm not having to make as many errors of inputs to pull to a new pitch attitude and hold it the open loop steps seems to be dead beat to the new pitch attitude.

On this configuration I'm also not conscious of having any particular amount of pull force in the turn or push force to get started down, it's a good blend. On the second configuration I liked that one, still I did have a tendency to get low in the middle and then level off but I didn't feel like I was hunting for the runway quite as much as I was in the first configuration.

The wheel forces and displacements were good.

Initial response - was reasonably good.

Predictability - in the flare there is still a little uncertainty about controlling h but in general pretty good - no particular special pilot inputs didn't notice a tendency to PIO.

Performance - I think that was desired.

Flare and touchdown - a little tendency to level off and get flat in the flare phase. A little floating in flare.

Airspeed control was no problem.

No unusual motions or control techniques.

PIO rating of 1. I didn't notice any undesired motions.

Through the Cooper-Harper scale - I think it goes up to the satisfactory to the first block of numbers and because I did have a tendency to get flat in the middle and then have to hunt for the touchdown zone I'm going to give that

a 3. I didn't think I had more than a minimal amount of effort to get in the desired zone. If I had wanted to get tighter than what we required then it might have been different but for this task I think it was a 3.

FLIGHT 736	CONFIGURATION: 1-3-7	PILOT: B
DATE: 9/14/83	HQ RATING: 7	PIO RATING: 4

PILOT: On approach I got low in-close, flat, I had to push over to get it on the ground. I ended up with too high a sink rate and I was a little bit leary about putting in a last minute input to try and correct that sink rate so I didn't really like that much. The primary undesirable portion of the task being in the flare. Shahan what did you put on that? (Shahan - desired touchdown). The sink rate at touchdown was maybe on the high side of the desired scale, it was higher than what I had intended and due to the fact that I was pushing forward to try to get it on the ground and when I saw that I had overdone it a little bit I didn't want to put in a last minute input and try to salvage it so the predictability there was in the flare and correcting for the excessive nose down was a factor. On that configuration I can pull to a new Delta/Theta and have to dither less with the column to stabilize on it. When I make an open loop step there is overshoot and residual motion after the step is completed it's not deadbeat like the other configurations were. Okay, we aborted that one, ran into a PIO trying to make sure that I got the desired sink rate so it kind of confirmed what my rationale for not screwing with the fine control on the last approach.

I'm going to go to the PIO scale first and I will say that it causes oscillations, divergent we don't know, I will give it a 4 on the PIO scale.

Feel or displacement forces were OK.

Response to inputs - the predictability of the final response is not good and leading to a PIO. In fact, even the initial response went up high again, tended to be a little surprising initial and final.

The pitch roll harmony is OK.

Special inputs - getting out of the loop down in the flare was a type of a special non-input.

The approach performance and airspeed control was satisfactory.

The flare and touchdown - the flare maneuver was obviously the critical point in both approaches. It wasn't adequate since we had to disengage on the last one. The unusual motions were the PIO. Control techniques were the staying out of the loop on the first approach.

The Cooper-Harper scale - here we didn't have adequate performance because we had to disengage so we had to branch off there to adequate performance not attainable with maximum pilot compensation in the flare and you have got a 7. The reason being the requirements to stay out of the loop largely in the flare maneuver to keep from generating a PIO.

PARRAG: OK, was controllability ever a question?

PILOT: That gets back to yesterday's discussion. Controllability in terms of catastrophic damage is something that I don't know since we didn't leave it engaged for long. If it was a little more clear that the PIO was going to be lost in amplitude and divergent then perhaps it would be convenient to go around so I think I want to leave it at a 7 for right now. We can discuss that a little more later.

FLIGHT 736	CONFIGURATION: 6-1-1	PILOT: B
DATE: 9/14/83	HQ RATING: 6	PIO RATING: 3

PILOT: The first run of configuration 4 was an abort due to possible flap mispositioning. This configuration feels more sensitive in pitch in that I don't seem to be able to get more response for a smaller input so it's relatively deadbeat in its step open loop response and doesn't require a whole lot of dithering to stabilize on our new Theta. I'll take that back, it does require moderate amount of dithering to get it stabilized.

I had the sensation of starting a PIO but didn't really develop because I sort of got out of the loop. I got deceled and just happened to make about the right power change but again that was just one data point. I don't think I could repeat that. So I am very skeptical of what I saw based on performance. I think this next approach will sort it out a little better.

Power changes too in near close trying to correct for the slow that it built up and I'm not quite sure how I got into that real slow situation, it really degenerated at some point without my realizing it until about the time you called and knowing, I wasn't looking at the airspeed indicator then, but I got the feeling that the airplane was rotating or settling one or the other I'm not sure which. Anyway the airspeed control was lousy. And the base turn the airspeed control didn't seem to be as free, seemed to be more requiring of inputs and attention than it had been with some of the earlier configurations.

Again that was a large element of luck and that approach felt like I was having to suppress a pitch oscillation and then stay out of the loop down close in the flare. I don't think performance really reflected it very directly, what I saw.

The wheel forces displacements OK.

Harmony OK.

Pitch sensitivity was somewhat, well, the response to pitch inputs seemed to be greater in that configuration than it did in the earlier configurations. There was a fair amount of iteration necessary to stabilize on a new pitch attitude a moderate amount. There was a tendency to PIO due to the sensitivity of the pitch response and I'm going to say it is somewhere between PIO 3 and a 4 - let me think that out for a minute. Definitely there was a compromise on task performance because it made me want to stay out of the loop

so there were undesirable motions and I'm a little bit torn between a 3 and a 4 there. Lets give it a 3 for right now on the PIO scale.

Airspeed control again was poor, I was decelerating there agaian when I didn't intend to be and didn't realize that I should be in the middle part of the final. So airspeed control was not too good.

Flare and touchdown again when I got in close I got a little flat, floated and I had to get out of the loop to keep from screwing it up.

PARRAG: Was that 3 or 4 on PIO rating or

PILOT: I'm going to call it a 3 right now. Adequate performance out of it but I'm torn between a 5 and a 6 here. There is extensive compensation to the in that I definitely had to get out of the loop. I think I'm going to call that a 6. Because of the pitch sensitivity.

BERTHE: This last one was a complete bust. OK, lets go with this one.

SARRAFIAN: Do you know which one we did have on of those three.

BERTHE: Okay, let's disengage.

FLIGHT 736	CONFIGURATION: 6-2-1	PILOT: B
DATE: 9/14/83	HQ RATING: 2	PIO RATING: 1

PILOT: Configuration 5 coming up. I have the airplane now. Cancel our comments on configuration 4. It appears that I am having to push quite a bit to get it back to the right speed. I have to push a lot to get it started down hill. On the open loop steps there is.

I am getting the impression of having to pull and push a lot more force on the colummn to make corrections than I was before going into the turn and corrected for altitude errors as well as rolling into the turn. Okay, I was reluctant in that case to apply as much force as I found was necessary to change the aircraft pitch attitude and sink rate and therefore I was behind. I got a sag in close, leveled out considerably and floated and managed to let it settle down but same heaviness in forces was evident through the entire approach and not I didn't find myself accustomed to applying these deflections in forces to make the airplane do what I wanted it to do so performance suffered. The second sample of configuration 5 with K_C twice the value of the first one. Open loop step there is a considerable amount at least another half cycle after the step is released half to three-quarters of a cycle. I tried to pull to a new pitch attitude and hold it there is a considerable amount of oscillation and tried to control it.

It feels as though it's not as heavy as it was and I'm not having to manipulate the controls as much as I was before.

I think this is going to be one that I can PIO if I'm not pretty careful on judging from my trying to close the loop on my Delta/Theta.

BERTHE: Don't prejudge it, sometines you get fooled by those things.

PILOT: OK on that one I had a lot of sink in close. I had to put on a lot of power and pull it off as it turned out. It didn't seem to be too oscillatory once I got the power adjusted and readjusted to correct for the sink in close I seemed to get back up to about where I needed to be and then from that point on the flare was relatively easy and I'm anxious to see another one to see what the glidepath up to the flare is like and then afterwards. The control forces were still a little heavier than some of the earlier configurations but they weren't excessively heavy before the gain was readjusted. So I found them to be certainly acceptable. I got a little worried there when I got low

in close to the flare that I wasn't going to be able to pull that out but I think I just happen to be lucky on the power adjustments. It felt there for a while that I wasn't really going to be in control of the situation and if I had to repeat it a number of times I might not be, I might have just made some unfortunate choices of power there but the actual flare maneuver after that part didn't seem to be difficult.

I liked that configuration and as a matter of fact it didn't - the fact that it was a little oscillatory in making pitch steps didn't seem to enter into it so characteristics on actual flare, I thought flare control was probably better than anything else I have flown today. I would say we got feel. Feel forces and displacements. The forces were a little high even with that gain setting they weren't pleasantly so. I was still pulling and pushing a little bit more than I was conscious of it. A little higher than what many of the other configurations had. As a result at times my airspeed deviated a little bit because I wasn't quite as much on top of it pulling to push to control the airspeed. The pitch response I thought was good.

Predictability was pretty good. It's the first configuration I have flown today where I felt like I could really control the h in the flare.

Pitch roll harmony was OK.

Special pilot inputs - none.

PIO - I didn't feel that I had any PIO.

Sensitivity was good.

Airspeed control - was a little bit - other than optimum due to this having to pull and push a little bit to effect changes or for whatever reason, I seem to have to be a little more conscious and scan airspeed a little bit more to avoid errors building up.

Approach performance - flight path corrections - I was lucky on the throttle on the first time so it worked out so maybe it's amenable to corrections, may have been a little bit of pure luck.

Airspeed control - not quite optimum.

Flare and touchdown - was good - no unusual control techniques I felt like I could control the flare and this is the first configuration that I have flown today that I really felt like I had the ability to get in here and control the flare.

No - the PIO scale I will call that a 1.

Cooper-Harper scale - it's satisfactory without improvement, and in general I am going to give that a rating of 2. The airspeed control is the only thing that kept that from being a really solid 2. I'm going to call it a 2 anyway because the most critical portion of the flare I felt like I could really handle and it's just the airspeed involved just a little more scanning of the airspeed indicator, so anyway I liked that one it's the best one I have seen today.

FLIGHT 737	CONFIGURATION: 6-1-1	PILOT: A
DATE: 9/14/83	HQ RATING: 5	PIO RATING: 2

PILOT: Comments on first configuration. We did three approaches I think two were desired and one, the first one, was not in terms of distance.

I think it's controllable. I think I could achieve adequate performance but I wasn't real happy within right to the last part near the ground and I did another approach because I wasn't quite sure why. It just seems a little sloppy right near the ground in controlling sink rate. So that I think it is satisfactory without improvement. I achieved desired performance two out of three in terms of distance but I was not happy with my touchdown performance although I likely achieved the three feet per second or close to it.

I had a worse feeling when I sampled the airplane up-and-away than I did when I really flew it. It seemed like it was going to be quite unpredictable but it wasn't quite as bad when I got down in close so I'm debating between a four and a five from what I saw.

The wheel forces and displacements - they were very light compared to the Convair but I don't have any serious comments there.

The roll pitch were matched.

The initial response - that seemed OK.

The final response - seemed a little slow, a little sloppy, unpredictable.

No special inputs that I noticed, that I could figure out.

Airspeed control - when I concentrated on it - was easy.

Flight path - except for the very last part was OK.

There was a problem with the touchdown rate I couldn't really get the attitude and get the sink rate under control right near the ground. It didn't really balloon or overcontrol from a PIO sense. Landing was more difficult. Crosswind not a factor but it seemed like we didn't have it quite out on the last one. But it wasn't a problem.

The rating - just reviewing that I'm having a little trouble because I didn't like it and I didn't know exactly why. I kind of smashed it into the ground

to get desired performance so I'm going to give it a 5. Because I could not control the sink rate near the ground.

No undesirable motions compromised the task but there was something there that I would like to reflect by saying it was a 2.

FLIGHT 737	CONFIGURATION: 6-2-1	PILOT: A
DATE: 9/14/83	HQ RATING: 4	PIO RATING: 1

PILOT: Comments on second one - I guess I'm not seeing things with great clarity this afternoon. Nothing is really standing out to me and I'm - I did fly one approach where I got it down within a couple of feet waiting for it to touch down and we floated merrily along. Do we get adequate on the first and then desired on the second. So you really have good crisp control, it's accurate you have a little tendency to float near the ground which disrrupts things so I think it's controllable. I think you can achieve adequate performance when you are aware of it you have to work at it a little bit, I don't think if I was nitpicking it was satisfactory and I think you could achieve desired performance once you realize what's going on but you have to work at it so I will give it a 4. If I flew it many times I likely would do better but I would anticipate that.

Forces, displacements - no comments there.

Pitch response - it seemed, I thought was excellent, it seemed quick, responsive and predictable. That is why I was angry when I floated.

Approach performance was OK.

Flare and touchdown - no problem with the flare in the sense of over-controlling but there was a tendency to float that could be compensated for but you did have to do some compensation right near the ground to get an accurate and smooth touchdown. Landing was more difficult.

Turbulence crosswind gusts were not a factor.

Good features - were the open loop control - looked excellent - it was crisp and accurate.

Reviewing the rating - Although I did not achieve adequate performance on both, only on the second one, when I was aware of the floating tendency I could compensate for it but I think that is a minor but annoying category and I will stick with a 4.

PIO rating would be a 1.

FLIGHT 737	CONFIGURATION: 1-2-2	PILOT: A
DATE: 9/14/83	HQ RATING: 7	PIO RATING: 2

PILOT: Comments on third configuration - OK, it's controllable. I couldn't get it down where I wanted so I could not achieve adequate performance. I didn't feel like I had any controllability problems so it's a 7.

Forces and displacements - nothing to stand out there.

Pitch roll OK.

Sensitivity - in the sensitivity sense.

Initial and final response when I looked at that separately seemed OK, it just was when I got down near the ground it seemed like I ran into some lift or something and it just wanted to float. The first one I tried to take the throttle off and I ended up staying where I was and having the airspeed go 6-8 knotts low and not getting near the ground any faster. The second one I cautioned myself not to do that and I just stayed at 3 or 5 feet past the touchdown zone so that is the primary problem. I didn't have a tendency to overcontrol but I know that it's just the tendency to float which didn't allow me to get the vehicle down where I wanted. I tried to with that last one but I couldn't do it. So the landing is difficult I didn't feel I was in any danger of hitting the ground hard I just couldn't get near it.

Effects of turbulence, crosswinds not there.

I would not change my rating.

PIO rating - rather undesirable motions in the sense that I couldn't do what I wanted with it near the ground but I didn't have oscillatory motions, and the task was compromised in the sense, although it was not a PIO so the undesirable motions - I couldn't get the response that I wanted that's abusing the PIO, scale I don't know. I'm going to give it a 2. I didn't see any tendency to PIO.

FLIGHT 737	CONFIGURATION: 1-3-7	PILOT: A
DATE: 9/14/83	HQ RATING: 4	PIO RATING: 1

PILOT: This is the fourth configuration - It's controllable. Adequate performance is attainable. It's not to me satisfactory without improvement. I would class the deficiencies minor but annoying because you have to learn the technique of pushing forward near the ground and I don't like that I guess. But you can do it with some confidence once you realize you have to do that so you can achieve desired performance 4.

The pitch response initial and final response I have no complaints about that.

Pitch roll harmony - is OK.

No comments on forces and displacements.

Special piloting techniques or inputs - yes, you must learn to push forward near the ground if you want to touchdown where you wish.

Airspeed control no problem.

Flight path corrections were alright on the approach but not so on the flare and touchdown. There is a little tendency to float that you had to push forward to contend with and you can do that, I think, with some accuracy but I just find that annoying and I gave it a 4 there for landing a little more difficult in approach.

No comments on turbulence, crosswinds or gusts.

Good features - a solid feeling about the control in terms of the pitch response but near the ground you had to pitch forward to get the sink rate the final sink rate and I didn't like that. I did not notice any PIO tendencies so it will be a 1.

My comments on that last one which is the fifth one that I actually have evaluated.

FLIGHT 737	CONFIGURATION: 3-1-3	PILOT: A
DATE: 9/14/83	HQ RATING: $5\frac{1}{2}$	PIO RATING: 3

PILOT: The rating - I think it's controllable, I achieved adequate performance and in fact I achieved, I guess, desired performance in both but there are several items that I'm not happy with so I could now say I could get the job done but I have at least moderately objectionable deficiencies and maybe even worse than that, so right now it will be a 5 at least. Let me just talk about it.

The feel forces in pitch are on the heavy side and it's distracting near the ground. I didn't notice the displacements so the pitch sensitivity seems low to me.

Initial response was such that I felt the forces so it was either slow or I had to pull hard to get it going, it just felt like it was a slow airplane. Sluggish, heavy.

Pitch roll harmony was not real great because the pitch was heavier than the roll.

Special pilot inputs - nothing stands out in my mind on that score. A tendency to PIO on the first one I had a little tendency to balloon and sort of a flight path PIO. I didn't notice it on the second one but maybe I was a little more careful with my touchdown and sink rate and everything and the second one was really quite good.

Approach performance - nothing there to speak of there. The flare and touchdown is where I didn't like it. I didn't like the accuracy with which I could control the airplane near the ground. It felt on the verge of flight path PIO like I said, tending to float, although I really didn't like the whole thing a whole lot. So the touch down accuracy was there, a little tendency to float and a tendency to overcontrol. Landing was more difficult, turbulence and crosswind was not a factor. The lateral control was a good feature. The rating again was - I did receive desired performance but I found I was having to work too hard to do that and I just didn't feel confident in doing it so I am ready to give the airplane - I'm going to give it a $5\frac{1}{2}$. I guess in general I was surprised that I did as well as I did. It's moderately objectionable, I wonder who made up that. 6 is extensive pilot compensation. Since I did get down where I wanted I can't say that I just feel like especially on my first

approach I saw things I didn't like as if something was potentially there that could build so I an going to stick with my 5½. And I am going to say that when I had to enter loop causes divergent oscillations - no. Tight control causes oscillations which are divergent, I thought I saw a little bit of that although it was more flight path than a high frequency like pitch attitude. So that would cause of oscillations yes, divergent no - undesirable motions compromise I like a 3 I guess for the PIO. I'm biased on the PIO scale because I always want things to be . . . .

FLIGHT 738	CONFIGURATION: 7-1-4	PILOT: B
DATE: 9/14/83	HQ RATING: $2\frac{1}{2}$	PIO RATING: 1

PILOT: This is the first configuration - a little bit of an overshoot on an open loop step and as far as making a pull to a new pitch attitude I seemed to be able to do that pretty precisely and with just a very small amount of dithering to stabilize.

Sensitivity fairly low but a noticeable amount of pull force necessary to go around the turn here toward the base and final.

Holding airspeed - seems to be relatively easy this configuration.

The aftermath of that first approach was that I felt like I had pretty good control of touchdown position, sink rate and glideslope and I was able to maintain airspeed fairly close without a lot of effort so generally I liked that good __________ tendencies.

________________ some pulling going around the turn on this approach but the airspeed doesn't seem to be suffering too much, but I am having to pull around the turn.

Feel - there is a little bit of a pull force necessary to go around the turn through the downwind leg and I was conscious of it I prefer to have less but it wasn't very objectionable it was just a minor sort of annoyance.

The other feel factors were not factors.

Response - felt comfortable what with the pitch response, initial response, predictability there weren't any special inputs necessary and I didn't see any tendency to PIO.

Airspeed control was relatively good.

Approach performance, again airspeed control was pretty good and I felt like I had pretty good control on flight path corrections. On the second approach I noticed I had the effects of the gusts more than I did on the first. I could tell on the first I didn't really get upset, I didn't get much of an upset.

Flare and touchdown - I felt like I had the ability to control the flare well and touchdown point, sink rate as well. No unusual control techniques.

The PIO scale - I think it is satisfactory without improvement. I think the only thing that I saw that I would like to have a little less of, is the pull force going around the second approach. I'm vasselating between a 2 and a 3 here. I think right now I'm going to cop out and call it a 2½ because I like it. The only adverse comment would be the little bit of pull to go around through the 90.

FLIGHT 738	CONFIGURATION: 8-1-5	PILOT: B
DATE: 9/14/83	HQ RATING: 4*	PIO RATING: 2

* Evaluation Inadequate

NOTE: Command gain used was high.

PILOT: Comments on second configuration - On the first sample of the second configuration I felt as if I had to be low gain and to try to stay out of the loop but I didn't really put it to the test too much on final. It felt as if I were going to excite a significant amount of undesired motion, if I weren't low gain and I think the fact that the touchdown happened just about right might have been something that I couldn't repeat too frequently out of a large number of samples.

- - - - - to putting in inputs was there based on the knowledge that the system might drop off the line rather than just the fact that the airplane might be divergent or oscillatory if I put in bigger inputs.

- - - - - I would put in an input to a new pitch attitude and then I would release it goes back to where about where it was. It doesn't seem in fact it's pitching down below where it was don't understand that it doesn't seem to be a real attitude hold system either that or the follow up on the attitude trimming a new attitude is very, very slow. It certainly is not holding attitude. If I try to go closed loop on it and put in an attitude change I can set up a real small amplitude limit cycle or a constant amplitude cycle of some lower gain I can stabilize maybe not exactly where I want to but I can stabilize in the vicinity of where I want to without a lot of small overshoots.

When I pull around the turn the results are confusing and before when I set up a new attitude I didn't want to follow up with trim and hold the airplane at a new attitude. I certainly wasn't conscious of any input that - - - that the aircraft motion preceded that disconnect.

BERTHE: I think we ought to skip on down to configuration 4.

PILOT: That configuration is a little inconclusive unless you want to ______ back ______ to one sample.

PARRAG: I thought you were reasonably well set up.

PILOT: I thought I was pretty well set up when I was about half way into the flare.

PARRAG: I agree. It is this one, crazy squelch. It's the squelch that's breaking.

PILOT: We have already commented on the feel and the response on the downwind an I still don't know for sure if - I would guess based on what I flew on the second approach that I was going to get reasonably good performance in the flare although I did detect starting the flare a little bit of undesired and unexpected motions but only a moderate amount.

Special pilot inputs - I was conscious on the first approach limiting my gain a little bit.

There is a slight tendency to PIO - the PIO scale I think that is a 2.

Airspeed control is OK.

Approach performance was OK.

Flare and touchdown was OK.

Control techniques - at least again the first approach where I carried it all the way through I was trying to get myself out of the loop to a certain extent.

Rating scale - I am going to say it is satisfactory without improvement (level one) and give it a 4. (Level 2 ?)

Moderate pilot compensation being removing myself from the loop at times to avoid exciting the airplane although I didn't really get to test it all the way down to touchdown on the second phase but I think a 4 is about the best I can do on that one.

PARRAG: Then it does warrant improvement.

PILOT: Yes it warrants improvement - I'd say it's not mandatory but it's in the second block.

FLIGHT 738	CONFIGURATION: 3-2-4	PILOT: B
DATE: 9/14/83	HQ RATING: 5	PIO RATING: 1

Configuration No. 4, it's the third one but it's No. 4.

PILOT: The motion of the step is pretty much deadbeat to a new pitch attitude for a step and release. In looking at delta/theta cosed loop I'm clearly not oscillatory but I don't always end up right where I hope to end up. It seems to always end up a little bit of offset.

On that approach in reacting to the gusts I always seem to end up flat and floated. I had to push some but then was able to apply some back pressure before touchdown and felt fairly comfortable in applying the back pressure to soften the touchdown itself. On that approach I also landed a good bit longer than where I would have preferred to land due to the floating tendency and the problem I had of having to push forward on the stick to re-acquire a negative $\dot{h}$. ____________ for the step input when it's released the attitude continued to drift for some period of time in the direction of the step. The impression I get is the sluggishness in Theta control when I try to close the loop.

Okay, I got the floating again. I don't seem to be able to overcome that floating tendency. Although I do feel better about this configuration than some of the others that are quoted because I don't have to push quite so much and once I push a little bit to get it down then I feel more comfortable about putting in a countering pull to soften the sink rate so my touchdown precision has gone way down. I can't put it right where I want to put it but I feel like I can control $\dot{h}$ reasonably well for the touchdown wherever it occurs. So that is a little variant on what I have seen before with floaters.

PIO scale - I didn't really detect any undesirable motions so I will call that a 1.

Rating scale - Feel - it is Okay.

The response - pitch is sluggish in response and because of its sluggishness and the length of time it takes to acquire what you are looking for well, predictability is not so much a problem in terms of pitch attitude. I guess it's just that the response is a little sluggish.

Pitch roll harmony is OK.

Special pilot inputs - in the landing there is the necessity to push over a little bit to get it down.

No tendency to PIO.

Sensitivity is not a factor except maybe the lack of it in pitch that is the initial response we talked about.

Airspeed control is OK.

Approach performance was fair, well, the approach itself was OK the flare and touchdown floating tendency.

Unusual control techniques - There is this need for a little bit of a push but then I can pull after the push to control $\dot{h}$.

BERTHE: Did we get desired performance (1,2,3,4) on those two landings? OK.

PILOT: OK, do I think it warrants improvement very definitely and I'd say I'm going to have to call that a 5 (adequate performance). It's kind of a good 5 because it's not real troublesome in $\dot{h}$ but touchdown precision has gone down.

FLIGHT 738	CONFIGURATION: 2-1-1	PILOT: B
DATE: 9/14/83	HQ RATING: 7	PIO RATING: 3

This will be configuration No. 5.

PILOT: Roll is a problem there noticed it a little bit during the approach and then in close when I flared and started to round out I got real deficient on thrust. _________ I was giving the airplane after the nose up pitch step or pitch half square that I took a long time to get the speed back and even with the large power disk it seemed to just barely creep back up to speed I think speed control is maybe going to be a symptom of this configuration - the lack of good speed control.

I touched down a little sooner than I wanted to. I decelled and I just settled right in beyond the wire but certainly sooner than what I had really intended at that point, it was a little late to add power and I couldn't seem to get anything by increasing the pitch attitude, I was already too slow.

Nose down it seems to diverge and I continue to travel in pitch more than nose up step and with closed loop OK I see him now. For closed loop input I was able to stabilize with a moderate amount of input to hold the new pitch attitude.

On the flare - floated I didn't float the first time both had the symptoms of getting slow and in that case I tried to correct by more aft stick and it just got me slower and slower, so speed control and touchdown precision suffered in that configuration in different ways. The first one I landed a little shorter than I wanted to and the next one I ended up holding off, getting slow and floating and landing a lot longer than I wanted to. The touchdown precision was bad, airspeed control was bad.

Had a slight tendency to PIO and I'd call that an undesired motion, a PIO rating of 3. Compromised the task.

Going down the comments.

The feel was OK.

Response to inputs - I guess the inputs that bothered me was the response to the pitch input necessary to flare in terms of airspeed control. It wasn't predictable.

Special pilot inputs were - I ended up having to do a little I guess there weren't any special pilot inputs, however, there was a tendency to PIO and I wasn't able to predict what I was going to get in terms of flight path angle and speed in the flare maneuver.

Approach performance was OK.

Flare and touchdown was not very good.

Unusual motions - I would get slow in close to the flare approaching the flare and throughout the flare. I wasn't able to find any control techniques to counter those.

The rating - adequate performance - I'd say that deficient that it requires improvement and the touchdown, I know that the speed was way off - how did the touchdown go? OK, I would say that even though I had desired range on the first, it wasn't where I wanted to be with the right sink rate. I wasn't short I was slow that the whole thing but as far as touchdowns point, I didn't land where I wanted to land, I wasn't really controlling it as well as I wanted to. The airspeed in the flare was a definite problem. I didn't think it was satisfactory and even though I got adequate performance, I wasn't happy at all with it. I'm going to give that a, I am really torn between the two categories because I really think it warrants improvement because of airspeed control so I am going to have to give it a 7. The other factors cause it to be a 6, but I'm going to leave it at a 7.

FLIGHT 739	CONFIGURATION: 6-1-1	PILOT: B
DATE: 9/15/83	HQ RATING: 6	PIO RATING: 4

PILOT: On that first approach I made a power reduction to continue to come down on the glideslope and I got a large response in terms of power, there was a surge pitch attitude change and the input necessary to put in for that bobbed off the system. I guess we won't count that other approach because it wasn't an evaluation approach.

This is approach no.1, configuration no.5 on today's card. On that pass I was conscious of trying to suppress what felt like a PIO starting and I misjudged my height. I touched down a lot sooner than I expected to on the runway. That is, the gear hit sooner than I expected to. I was thinking that I probably would make it up to the wire without too much throttle so I think that was a combination of the airplane and my misjudging the height and being content to leave things where they were and accept the touchdown about on the wire I thought. When in reality we touched down just short. On this configuration I notice a little bit after an open loop step I notice that the attitude returns toward the original attitude about 20% and I can make a when I try to be high gain and pull to a new pitch attitude there is quite a bit of cycling of the column I try to steady on the new pitch attitude. On that configuration I'm a little bit confused due to the fact that I didn't feel so much like I was PIOing that time. I'd like to take another look at that one.

BERTHE: It's going to shorten your day we'll probably lose the last configuration if you do. It's up to you.

BROWN: OK, let's look at it anyway because I don't feel like I'm making a good call on it right now because I have two conflicting observations on that one I felt like I was able to make pitch corrections to control my $\dot{h}$ a lot better that time even though I still didn't get the touchdown exactly where I wanted it. I think the first one I know there was an element of not knowing what the height was exactly. There should be more calibrated now. The initial impression based on that task was that I had fairly good $\dot{h}$ control but I didn't have the touchdown precision that I would like. On the first pass it seemed as if I was trying to suppress an oscillation and was harder than it was on the second time, so I would like to look at one more time.

Configuration - Also this configuration feels fairly slow in its initial response. Maybe it's because the forces are a little bit.

On that approach I did have to suppress an oscillatory tendency I levelled in close trying to control my $\dot{h}$ in touchdown point, floated, touched down longer than I wanted to, touchdown sink rate was OK. Precision of the touchdown point was pretty poor and I did have to work on suppression and oscillation. Response to the inputs in that I had an oscillation there to PIO. The initial response to the control seemed to be a little sluggish perhaps because of the forces being a little bit heavy in the longitudinal axis.

Approach performance was okay until I got in fairly close I was seeing some oscillation in the approach in close trying to control airspeed and gamma.

Flare and touchdown - the flare maneuver was not done very well because of the fact that I had to suppress the oscillation - touched down longer than I intended to. I got slow also in the process of holding what I had to avoid oscillation so airspeed control was poor at the start and during the flare.

Unusual control techniques - I was staying out of the loop a little bit suppressing oscillation.

On the PIO scale - I'll give that a 3. Well standby, it was an oscillatory tendency I'm going to give that a 4. On the Cooper-Harper Scale I got adequate performance but I think it needs improving.

Airspeed control is poor I'll give that a 6. In order to get better airspeed performance I'd what I would call adequate, I think the airspeed performance on that was a little less it definitely wasn't desired it was borderline. I don't think it was really adequate it was just on the border of being adequate so I'll call that a 6.

FLIGHT 739	CONFIGURATION: 6-1-1-1	PILOT: B
DATE: 9/15/83	HQ RATING: 4	PIO RATING: 1

PILOT: This configuration is less overshoot, less overturn to the initial position for an open loop step elevator input and I'm able to stabilize on Delta/Theta a little easier than I was on the last configuration. Okay, I'm pushing to get this thing around the turn and I'm still slow, are you sure throttles are hooked up? On that approach I tended to get slow in close, I tried to squeeze some power back on but I still stayed low.

BERTHE: Where were your throttles that time coming over the fence?

PILOT: Beats me, I thought I was fairly well squared away but then when I started the flare maneuver I got slow again.

BERTHE: Well my throttles were pretty far back so I just wondered where yours were.

PILOT: I can't tell you for sure but I thought the airspeed was fairly well established then I went into the flare and got a little bit slow and in the process of extending my trying to get up to the proper touchdown point I did not feel oscillatory in that case but I felt like the airspeed control was not very good. This configuration is a lot easier to stabilize in with the delta/theta. I liked that configuration pretty well, I didn't have the airspeed problems of any great magnitude that time but I still have a feeling that the response to thrust controls is different than it has been in the past. I don't recall lags of the length that I was experiencing on both of those passes, in spite of the fact that the approach angle has been maybe a little bit steeper.

Third configuration off, and instrument power is off. Okay, Column, wheel forces, displacements, sensitivity all okay. Initial response is good. Predictability is okay. No special pilot inputs. I don't really feel any PIO tendencies. Airspeed control was okay. Approach performance again not much comment. Flare and touchdown, I felt like in general I had pretty good control of both the flare and the touchdown point. Although on the first one, I think I was pushing just a little bit to get it down but that's the only thing that may border a little bit on control technique required. I think there was a little push first. The record should show that up. Okay, on the PIO scale, well, let's give that a 1. Okay, you got a guy right there.

BERTHE: Okay

PILOT: On the Cooper-Harper scale

BERTHE: Ready for your gear?

PILOT: Satisfactory without improvement but for whatever reason, I didn't seem to have much - the same kind of response to thrust change. And I don't really know, understand that. Let me think here a bit.

BERTHE: Breaking into to us. I think I'll go down a little bit.

PILOT: OK, I'm going to say that because of the thrust response that I was getting, that it took moderate compensation to achieve desired performance. I'll give that a 4.

BERTHE: Phil, the thrust is not part of the flight configuration.

PILOT: Well, it may not be but it sure ties in when it gives me a heave or a pitch that then requires me to put longitudinal inputs.

BERTHE: Okay, I think one of the problems is were coming in at a level turn all the way around the close-in and then you're having to go to flight idle to get down and it's not having time to get stabilized. I think if you come through the 90 about 300 ft lower, it would be more stable coming across.

PILOT: Well, I think I was flying more or less the same pattern the other day. maybe I wasn't. Maybe I was flying lower.

BERTHE: you set?

PILOT: Okay. There doesn't seem to be much attitude holding the airplane after a step input. It seems to return to pretty much to the original pitch attitude. And there is a moderate amount, a small to moderate amount of activity necessary to stabilize our new pitch attitude. I have to push quite a bit now to get the airplane started downhill and hold speed. Holding a push force on the stick.

BERTHE: It's going off at the end. He's turning.

PILOT: Now, I've been waiting for at least 4 or 5 seconds for power. Really believe that I couldn't have been doing things quite this differently today.

BERTHE: That's work.

PILOT: Okay.

BERTHE: Gear?

PILOT: Yep gear. Okay, I thought it was relatively easy to make the approach and touchdown point and flare with that configuration. I liked it pretty well except the fact that I had to do a lot of pushing and I did some trimming but didn't seem to -- maybe I don't hold it on long enough but it didn't seem to do much good. Didn't notice any tendency to oscillate there and I felt like I could predict and put the airplane where I wanted it. I'm still surprised at the power response. I don't recall it being like that yesterday. Put a (3) and a (4) in parenthesis and a note that power is what caused me to call that a 4 and we'll try to sort it out after the fact. What configurations have we flown - 5? and what other numbers on your chart?

FLIGHT 739	CONFIGURATION: 6-2-1-1	PILOT: B
DATE: 9/15/83	HQ RATING: 3	PIO RATING: 1

BERTHE: 5 and 6. Were on 7.

PILOT: We're on 7. Ok, I may be further back on the power because I'm putting less power for that glide slope.

BERTHE: It's only 5 or 6 knots. Not a whole bunch.

PILOT: It's - and they're coming across the fence. I'm pushing to go down even though I try to trim this out here and get a level flight before we start.

BERTHE: Altimeter check 1600.

PILOT: Okay.

BERTHE: I think we'll be all right this time.

PILOT: OK, again I'm conscious of some push force.

BERTHE: OK, now we're down on altitude early and now you'll be up in the operating range coming across the fence. I think you'll see something different.

PILOT: See the glide slope. We're just still a little bit high on it.

BERTHE: We're in good shape here.

PILOT: It's a little slow here so I add more power on. Okay, I felt like I had good control there. Power wasn't a problem. I put on more power on that approach because I'd gotten down to about 128 knots. I had a little excess power on to try to bring my airspeed back up to 132. Power response was the problem. Okay, the - I guess the only thing that we've got is - -

BERTHE: We've got to have configuration change, right?

PILOT: Yep. Okay. The wheel forces and displacements were OK but the - that wasn't always what I wanted and yes they're off. I had to push around down on the final and through a considerable portion of the final. There was some push force on the wheel. And it took a lot of trim to try to nullify that.

That was the only special unusual sort of input. Didn't see any PIO sensitivity or tendency. Airspeed control was fair. Fair to good. I didn't like this having to push coming down hill on final. Approach performance was okay. Flare and touchdown performance was relatively good. I felt like I controlled the situation. I did get a little, maybe a little bit flat in the flare especially on the second approach but I was able to hold off without getting too slow and touchdown on the right h and the touchdown point. No unusual control techniques except for the -- well, in the flare there wasn't really much there wasn't any unusual control technique. On the Cooper-Harper scale, I'd give it -- correction - on the PIO scale 1. There wasn't any - I didn't see any tendency to oscillate, or to undesired motions. And I think it's satisfactory without improvement. The only thing I didn't like about it was the pushing business on the wheel to come down hill so I'll give that a 3.

NOTE: Result of washout, make it attitude command.

FLIGHT 739	CONFIGURATION: 4-3-7	PILOT: B
DATE: 9/15/83	HQ RATING: 7	PIO RATING: 1

BERTHE: Configuration 8.

PILOT: Okay, on that configuration, maybe the gust was late but it floated and floated and floated to my surprise and I did a little tiny bit of pushing and then just had to hold what I had, and landed long. Up to that point, I didn't see anything that didn't look okay about the configuration and also it was not adequate. The pitch attitude stalls.

BERTHE: We could guess that.

PILOT: We got pretty hard damping - just a tiny little bit from oscillation after the steps were moved and for closed-loop delta/theta, I'm able to stabilize so I want just a small amount of column activity. There's a very pronounced float and the discrete gust came in plenty of ---

BERTHE: Go down aways?

PILOT: Can't fault it, due to late gust. OK, as far as feel - everything was okay there.

Response to the input - the up-and-away inputs looked great. There wasn't any tendency to PIO, no special pilot inputs. Airspeed control was OK. The glide slope performance looked reasonable. The only problem was flare and touchdown and there was a terrific tendency to float. I pushed a little bit but I was so close to the ground, I couldn't really push too much and then didn't feel like I could push to get it started and then take out the push and make a nice controlled touchdown.

So in summary - the floating and lack of precision in touchdown was very disconcerting. $\dot{h}$ wasn't really a problem. There was just more a gamma matter in trying to get the airplane on the ground, and at the right place. PIO rating would be a 1 and I think I was long on that one. Was I out of the adequate zone or just -- yeah, adequate. I think the tendency is more to be not adequate than it is to be adequate. I'm going to branch over to the adequate performance not attainable with a tolerable pilot workload and improvement required and give that a 7 now that there's some room for tradeoff there. I could have dropped the nose and I'm not sure if I'd done that exactly what would have happened. I don't know how much $\dot{h}$ I would have built up so there's

a little bit of a question there but because of the -- the floating tendency was so pronounced, I'm going to leave that a 7.

FLIGHT 740	CONFIGURATION: 8-3-5	PILOT: A
DATE: 9/15/83	HQ RATING: 5	PIO RATING: 3

PILOT: Comments on the first evaluation. It's controllable, I could achieve adequate performance. It is satisfactory without improvement - my first approach was excellent. My second one floated a little bit, although I was about to squeeze it onto the ground and I did get a little slow because of the floating. I think the sink rate would have been okay. So I'm going to say it's either a 3 or 4 and I will make some more thought in a second.

Wheel forces and desplacements - I have nothing that I can remember that stands out there. I did think the airplane was a little on the slow side but it's predictable enough. So the initial response may be a little slow.

Special inputs - the second one I flared because of the gusts I ended making a large input near the end because I didn't have it settled down and I flared too much and ballooned slightly and floated. The first one everything seemed to work out quite nicely. So the velocity control was not good on the second one.

The approach performance was okay.

Flare and touchdown - there was a tendency to float on the second one so the accuracy wasn't quite as good as I would like to see. Landing was a little more difficult. The gust was bothersome on the second one, it came at a time that bothered me the most.

Good features - I think it was entirely controllable and you could achieve adequate performance. The second approach gave me a debate I would have likely based on the first one said it was satisfactory. The second one I saw some characteristics when I had to do things rapidly that were not evident when I had things more in control in the first case so I will review the rating again and say that certainly, adequate performance is attainable. Is it satisfactory without improvement - I'm not sure I can think of what I would improve specifically but you can achieve desired performance and based on some of the problems that came on the second one, I will give it a 4. If I only looked at the first I would give it a 2.

BERTHE: Safety pilot comments are that we took it over because there was an over-rotation and the airplane got slow before it touched down. We are ready to engage when you feel is ready.

PILOT: I could feel that over-rotation that I got involved in near the end PIO is missing - undesirable motions tend to occur task compromised I guess I would have to say yes but it's a screwball situation with a 3 PIO rating.

BERTHE: We will engage, start out turn and get our confidence record on the next pass.

PILOT: I guess on that first one all the way around on this approach I thought about it some more and I think the gusts are coming in lower than I have seen before but I'm not sure certainly this last one that I just flew it upset me at a time when I really had to get in there and I can see some over-controlling, over-rotation then ballooning so I really think my first approach influenced me and I would like to give the airplane a 2 on that basis. I'm talking about the last configuration. I really think all things considered with the airspeed control and remembering that I, and I'm influenced a little bit by Chuck reminding me subtly, I can see that I overcontrolled a little bit in pitch anyway I'm going to change that to a 5 because I don't think that was desired performance, besides I don't like saying a PIO rating of 3 with a 4. Which is another way of saying it was inconsistent.

FLIGHT 740	CONFIGURATION: 8-2-5	PILOT: A
DATE: 9/15/83	HQ RATING: 8	PIO RATING: 4

PILOT: Comments on the second evaluation. Again, the first approach was not too good, not as bad as the second one. The second one was not good, I think it's controllable but I do not consider adequate performance attainable. I really got into a somewhat low frequency PIO near the ground and I could feel myself battling to suppress it so I think that is inadequate performance.

Controllability not in question - Oh, I think I was having to work at controllability there so I think it was an 8. The second approach was when I got into a damped PIO on the second one.

So the comments are - The forces displacements - no comments there.

The control in pitch sensitivity seems to be well damped.

Initial response doesn't stand out but the predictability of the final response did, particularly on that last one the combination of trying to get down, get the sink rate up, get that gust have to push over to counteract the gust and its reduction of the sink rate overcontrolling that and having to put in a large input to stop the airplane from hitting the ground then I add three oscillations before I got it smoothed out enough that I was in control to touchdown and I had to abandon trying to get it down in the desired area.

There was a tendency to PIO. The sensitivity was not a problem in the pitch.

Airspeed control - I don't remember, it was okay.

Approach performance was OK.

Flare and touchdown there was a tendency to float, a tendency to overcontrol in pitch attitude.

Unusual control techniques - I had to really concentrate to suppress the oscillation so the landing is more difficult - the gust seems to be very effective in disturbing my task today and it's doing that.

Problems - I have already noted.

The rating again, I do think it's inadequate performance. I do think the second approach in particular that I was having some controllability dif-

ficulty having to work hard for an 8 PIO rating enter the loop divergent oscillations - no. Causes of oscillations - yes. Divergent - no I was able to damp them out so it's a 4.

FLIGHT 740	CONFIGURATION: 8-5-5	PILOT: A
DATE: 9/15/83	HQ RATING: 5	PIO RATING: 3

PILOT: Comments on configuration 3. It's controllable - I thought I would do much better than I did do with the first one. I thought I had it made, it floated a little bit I overcontrolled slightly went beyond the desired. The second one I landed before I thought I was going to. I just didn't have the control, although, I landed I think just in the desired area. So up-and-away it felt much better than the performance that I got so I was a little confused about that but I think I could do the job but I don't think it is satisfactory without improvement. Some of those things something was causing what I saw so I think only adequate performance was attainable and I say even though I landed in a desired area I landed before I wanted to and harder than I wanted to, so I wasn't controlling it in a desired fashion. So I think it's a 5. I'm sorry to say that because I thought it was going to be much better than that.

Wheel forces and displacements - no comments there.

Pitch and roll sensitivity - likewise OK.

Initial response - if I put in smooth inputs it felt like it was a reasonable airplane, if I put in quick responses I didn't get any initial response. It felt good up-and-away when I was looking at it. The predictability down in close was a little poor, not satisfactory.

Pitch roll harmony was OK.

Special pilot inputs - I didn't notice any.

Tendency to balloon - I don't think I saw a PIO in that sense.

Airspeed control is okay.

Flight path - no problems there.

Flare and touchdown there was a tendency to float a little tendency to over-control. I could not control the sink rate at touchdown in a predictable fashion.

Approach and landing was worse - most difficult.

The gust gives you a good control problem. I don't know why today I think the disturbance that the gust is putting in is doing just about the right thing it is upsetting my trajectory and it's good. Timing is good.

The rating a disappointing 5 and I really don't think I got the job done with desired performance so I will give it a 5.

PIO rating - oscillation, undesirable motions tend to occur - yes - task compromised, I guess it was an occasion so that's a 3.

FLIGHT 740	CONFIGURATION: 8-1-5	PILOT: A
DATE: 9/15/83	HQ RATING: 4	PIO RATING: 1

PILOT: Comments for the fourth and final configuration . It's controllable I probably could have achieved adequate performance. Is it satisfactory without improvement, question, I think not, it has a characteristic that you have to push forward near the end that I don't really like too much. I tended to not be able to flare in a uniform fashion so that I and on the second one I got a gust late in the game and I had to correct and I tend to level out and float a little bit, although, I have good confidence that I have good predictability so I think it's a 4.

Forces displacements - nothing noticed.

Harmony was okay.

Roll, pitch sensitivity - was satisfactory.

Pitch initial response was good.

Predictability I thought was satisfactory. Then I just had a feeling of confidence that I could muscle the airplane a little bit as I did on the last one with the late gust and not get into trouble. So that was good. Airspeed control was OK. Spiked on the last one a little bit ahead of myself, I was remembering the airspeed I got on the ground as the nominal airspeeds.

Approach performance was good.

Flare and touchdown - slight tendency to float, I tended to exaggerate a little bit when I had to work on that late gust on the second one. I have to squeeze it on the ground by pushing forward. It tends to round out you tend to round it out and it holds a couple of feet in the air and then you have to push it forward to get it on the ground which is okay as long as you don't have to do anything rapidly you just lose a little predictability in touchdown.

Approach and landing - landing was most difficult the gusts were effective in disturbing my pitch task. The last one was a little lower than I have seen and it did destroy my performance to some extent but I still think I was able to achieve desired performance.

Good features - were the solid feeling of the airplane I put it that I had confidence to get in there if necessary and stir things up, move the airplane where I wanted aggressively and it could be aggressive if need be.

Overall Cooper-Harper rating - I sure like to give better ratings I guess although, I'm still saying I could achieve desired performance with some compensation required in the sense of having to push it on to the ground.

PIO rating - oscillations - No undesirable motions tend to occur no I don't think there is anything there that stands out. Slight tendency to overcontrol on a couple. I'll give it a 1. Pilot rating 4.

FLIGHT 741	CONFIGURATION: 8-1-5	PILOT: B
DATE: 9/19/83	HQ RATING: 4	PIO RATING: 1

PILOT: This is 9/19/83 and Ron you can take out 8 knots of crosswind if you want. Flight 741 configuration no.1 for the day.

BERTHE: Okay, we're quite high.

PILOT: Okay, we're still shooting for 800 at the perimeter --

BERTHE: Yeah.

PILOT: Okay, you're probably ready for landing. Flaps secure. Fluids, pressure, nosewheel centered. Yeah anytime.

BERTHE: I don't think it went in from the right direction. Take it out.

PILOT: I don't think so either.

BERTHE: OK, let's get squared away on which direction across. The crosswind is from the left.

PILOT: The first configuration to an open-loop pitch step and release. The airplane returned in a well damped fashion. Very close to the original theta and it's -- I need to pull to a new theta, closed loop and be stabilized on the new theta. The first pass with the right crosswind correction, I wasn't conscious of any large input to cause the system to disconnect.

BERTHE: And the flaps.

PILOT: It did seem that I was leveling off some. I was going to become high, I wasn't going to get down quite as early as I wanted to get down after starting the turn. But I wasn't conscious of any large input to abort the approach. Gust input was what aborted the approach.

BERTHE: Correction for the gust --

PILOT: Well, I could tell that I was not coming down as much as I wanted to. I didn't think that I made much more than a throttle input of any size at all. And that column input that I did make along with the throttle change was nose down.

Third pass - Let's see on the first crosswind was put in the wrong way, the second we disengaged due to a correction for the gust input and the third one, the K_c has been lowered. This is the third one coming up. Okay, on that approach, I was conscious of getting high when the gust came in. Having difficulty in working the control and the gamma got low in close leveled off, then I came back on the power, started to sink again from my flat, low-in close condition and then when I tried to control $\dot{h}$ there after low and flat, I wasn't able to do it, and landed hard, also landed longer than I wanted to.

BERTHE: Okay, flaps.

PILOT: OK, may have been desirable for touchdown and long but was not well controlled from my perspective either $\dot{h}$ or touchdown, even though they were in that range. I was working and I wasn't able to control. Surprised at the hardness of the touchdown. I knew I was going to land long from what had been happening up to that point. Surprised at how hard we touched down. It was obvious flying around the pattern that there was going to be a sluggishness in response on glide path response. Of course, all I can see is theta, but theta seems to be responding satisfactorily to my inputs. I wouldn't rate it as being excessively sluggish based on what I can see up here.

BERTHE: Pretty high Phil.

PILOT: Okay. I think that was strictly luck. I made a large power change there and just happened to make the right one. But I don't think that's something I could repeat.

BERTHE: I thought that was beautiful.

PILOT: Well, I think that was deceiving. Okay, on the feel, the forces and displacements were satisfactory and instrument harmony was okay. Response to the inputs at altitude - they were good. Was a tendency to PIO in pitch so I'd give-- well, I'll go back and get that for you. Gear ratio performance was OK into the start of the player, was okay. Flare and touchdown, there was a problem with controlling glide path and $\dot{h}$ approaching it during the flare. There weren't any unusual control - well, there were unusual control techniques. It was difficult to control both parameters so that is $\dot{h}$ and gamma precisely and could maybe previously make comments on glide path and touchdown. The PIO wasn't a factor. I'm going to give it a 1. Because I couldn't precisely control gamma and $\dot{h}$ it warrants improvement definitely in that category. Performance in both cases turned out to be in the adequate range. But it is not satisfactory without improvement. What bothered me most was the tendency to have to make manipulations to control gamma in close, large power

changes and come out okay. So I'm going to give that a 6. And then the secondary factor is the tendency to --- for the gamma to go towards zero and level out float and then have to try to control the flare which again, I don't feel I can do easily and just barely adequately. Pitch response is very, very sluggish to an open loop step and release. The airplane is fairly well damped, the new pitch attitude change where the release or the new pitch attitude is close to where the release point was with maybe about a 15% overshoot back toward the original theta. And pitch attitude changes closed loop were difficult to do precisely.

FLIGHT 741	CONFIGURATION: 8-2-5	PILOT: B
DATE: 9/19/83	HQ RATING: 7	PIO RATING: 4

BERTHE: Okay, we're pretty fast. The DLF is saturated.

PILOT: Let me slow down here. And I'm not able to precisely make that or quickly make it. Those comments were for the second configuration (8-2-5) which we're looking at today on the 19th. Okay, we definitely had a PIO going there. Just lucked out in terms of touchdown on the flaps. The bottom we'd get one cycle and touched down more or less in the right place but it was again happenstance not control. There are large power changes to control gamma and at the same time I got out of phase in controlling pitch along with the power. Coming up is the second one of the second configuration of the day.

BERTHE: You are a little close - 1500 ft that is what I have got.

PILOT: In the last pass on the attempt to get on the runway the airspeed control was lousy too and in the process of going through the PIO or whatnot I had a lot of trouble on the left side of the runway. On that one on the last one and having to make a large power parachange getting it to a pitch PIO ______ having to push to land and landing to level off making us land long and push vain I wasn't able to control h well it was mainly a push and hold to prevent another PIO. I wasn't able to handle lower the h to try to make a nice soft touchdown, I was having to push to try to get it on the ground. Instrument power is off here.

The displacements were okay.

Response to the inputs however was not good. The initial response was sluggish. Final response in terms of pitch attitude was not very predictable, special pilot inputs in close if you try to stay out of the loop as much as possible will be fairly low gain and wait and see what happens, but the lack of predictability made that hard to do very well, it was pronounced tendency to go into PIO's.

Airspeed control was not even an issue that I could monitor in close to being busy with trying to prevent or minimize the PIOs. Approach performance was good until the gusts came in fairly close and then I had to make large throttle inputs to try to control gamma.

The flare and touchdown was very difficult to do, couldn't do it in a precise way at all. PIO'd at large gain changes in gamma and the control techniques were trying to suppress the oscillations and trying to take lucky guesses as to what I was going to do with the throttles and then just hope that it worked out. On the PIO scale we definitely had oscillations, they seemed to be more limit cycle or constant amplitude than divergent so I guess I will rate it as a 4. I don't think they were necessarily divergent but they certainly weren't damped significantly elither. And on the other scale. We are in as far as I am concerned adequate performance wasn't attainable. How did the touchdown $\dot{h}$ lineup look? Distance, well be that as it may I don't consider my performance was what I would call adequate and I think it's a matter where improvement is required. That is going to give me a little bit of a problem because 7 says adequate performance is not attainable so I'd say any PIO is not adequate performance. You've got a PIO and you are worried about it being either constant amplitude or possibly being divergent, I'd say it's not adequate. I don't think we have enough performance parameter here and that should be one so I'm going to call that a 7. It's not a very good 7 at that.

FLIGHT 741	CONFIGURATION: 8-3-5	PILOT: B
DATE: 9/19/83	HQ RATING: 7	PIO RATING: 3

PILOT: Third configuration of the first flight of the day. It's another one of these real sluggish configurations where to an open loop input I get a slight overshoot maybe 10% or return to the original theta I release.

BERTHE: I'm going to stay with you on this one because this is going to be a bad one.

PILOT: I can believe it - I also tried the closed loop to make a closed loop delta/theta, I'm doing a real poor job.. On that run I had to make large changes and an oscillation was in the process of starting. I was lucky with guesses for power and I had to stay out of the loop a good bit and it was just lucky that it just happened to land in about the right place but there was a not much control being exercised because of the fear of further provoking a PIO and I didn't even attempt to make a pitch input of any significance to control $\dot{h}$ so I think the outcome was lucky rather than a result of being a configuration that could be flown in a very controlled fashion. Started pitch down in adequate $\dot{h}$ but I think somewhat due to happenstance I didn't really feel that I had control over $\dot{h}$ or gamma that was significantly better than what I had before. The only fortunate thing was that the PIO hadn't progressed as much into a PIO by the time I got to the pitch down so on that time as I had in the other two cases.

BERTHE: We are getting a little too slow.

PILOT: Okay on that pass I saw the same symptoms that I saw before I was I could tell when I got in close here it was controlling gamma that probably was getting slow because I could see some attitude change. I wasn't able to make a reasonable attempt to scan the airspeed indicator at that point and part of that was due to the fact that I was trying to be smooth and not high gain so I was giving up that airspeed control I tried not to PIO.

The samples for this configuration - there has been a real difficulty in trying to handle the discrete gust and to get back down on the glide slope and control it. The displacements and course relationships are okay, however, the responses I have commented before are very sluggish and it's hard to control pitch attitude precisely.

Special inputs - on the general we will talk about them in terms of flare and approach I guess. There is a tendency to PIO. I have not PIO'd as much this

configuration as the last and I think that could be the configuration rather than my control technique.

Airspeed control - has been pretty poor in close and that was the reason for the abort on the second one because of the airplane getting slow.

Approach performance way out has been reasonable although I haven't been very tightly trying to maintain. I haven't had to go on the ILS so I have been pretty loose on the glideslope. The problem starts in close right after the 800 ft point right after I turn in and then start turning back to parallel the runway. Particularly there is a problem whereas with the flare when the descrete gust goes in and gamma is very hard to control. There is a tendency to PIO and therefore, I have to try to be low gain and try to stay out of the loop and those are the techniques that are necessary. There is a tendency to have to make large power changes I have to guess at them and maybe to get flat and low and have to push to go down and I'm going to call the PIO scale, I'm going to call it a 3. The task is harder I couldn't quite see that in either case did I get PIO but there was certainly undesirable motions that were occuring so we will call that a 3 on the PIO scale.

On the Cooper-Harper scale I'd say no, I did not get adequate performance and again I'm going to call this a 7.

FLIGHT 742	CONFIGURATION: 8-1-5	PILOT: A
DATE: 9/20/83	HQ RATING: $5\frac{1}{2}$	PIO RATING: 2

PILOT: Comments on the first evaluation. It's controllable right now. I'm going to say I can achieve performance so I am real happy about that. It's really not satisfactory without improvement, it's not predictable. I think I hit on the desired area but I don't think that it had adequate performance or desired performance in the sense that I couldn't control the sink rate in a predictable fashion so right now I think it's at least a 5. Let me talk about it some more.

I did not notice anything in the forces or displacements. The roll pitch sensitivity was okay. The pitch response it seemed reasonable to me although the overall predictability of my flight path was poor.

Pitch roll harmony - no comments there.

Special pilot technique inputs - I didn't develop any. I didn't feel like I was PIOing.

Airspeed control - was okay.

Approach performance - no complaints there.

The flare and the touchdown - there was a tendency to float. On my first one I didn't get into the flare in a good orderly fashion but I couldn't correct it and I ended up floating quite a ways and I kind of discounted that one as getting back in the groove. The second one I did fairly well on in terms of sink rate and touchdown but it does tend to float. The third one I touched down fairly smartly and most importantly, not when I wanted to so it's not predictable down in close for the touchdown. Landing is the worst. A big crosswind today but I didn't notice that affecting my task in any off nominal fashion.

The overall rating - I think it's controllable and I'm going to say adequate performance is attainable, although it's not satisfactory. I think it is one you would like to fly five or six times. I'm going to say it's a little worse than the 5 or $5\frac{1}{2}$ mainly based on my first efforts.

PIO rating - I didn't notice any oscillation.

Undesirable motions - I tend to overcontrol a little bit so I will give it a 2.

I guess I get a little confused because I don't think I had a PIO but I do think I didn't control so I don't know what the reason was I will give it a 2, I just couldn't control the flight path the way I wanted. When I entered the loop it causes oscillations - yes divergent I really don't know, I don't know if that first one would have been divergent or not it is kind of academic, it's a 4 or 5, I'll say it's a 4 for now, so it's a PIO rating of 4.

FLIGHT 742	CONFIGURATION: 8-5-5	PILOT: A
DATE: 9/20/83	HQ RATING: 7	PIO RATING: 4

PILOT: Comments on the third - I think it is controllable whether you could achieve adequate performance or not I'll debate a little bit in a moment. Let's say you can for now it's certainly not satisfactory, I don't have the precision control near the ground it has a tendency to float. The last one I got a little pitch bobble going and it distracted me from taking the throttle off, I ended up high and not in very good shape so right now I think that it's at least a 6. I will review that.

I have no comments on feel.

The initial response seemed reasonable, however, down near the ground I got into pitch bobble overcontrolling small amplitude PIO in pitch which transferred my attention from getting the sink rate organized and destroyed my capability to get down near the ground and took away my workload capability in the throttle and I just locked on to the pitch and ended up really messing up the landing so the airspeed control was poor on that one because I was overloaded a little bit in pitch wondering what was going on.

Approach performance - was okay but the flare and touchdown there was a tendency to float and there was a tendency to overcontrol. I couldn't develop any techniques that could help me.

Landing - was clearly more difficult.

Turbulence - crosswind gusts - not a factor, the gust is a good task disturber.

The rating then - I think it's controllable. OK, I think I should have done better but I didn't so I don't think I could achieve adequate performance overall so I give it a 7. I didn't think controllability was in question in the sense that it was going to go anywhere but I did have that bobble so I give it a 7 rating and a PIO rating - When I initiate abrupt maneuvers I do cause oscillations which were small amplitude and not divergent so it was a 4.

FLIGHT 742	CONFIGURATION: 8-2-5	PILOT: A
DATE: 9/20/83	HQ RATING: 8	PIO RATING: 4

PILOT: It's the fourth evaluation. It's controllable, I cannot achieve adequate performance. Controllability is in question in the face of the task I don't think these airplanes some of them that I have seen, this one can handle it you just cannot be aggressive with the airplane or you get into an overcontrolling situation and you have to abandon significant portions of the task like the throttle, like the touchdown point. So I think that considerable pilot compensations are required for control and the airplane has major deficiencies, I'd give it an 8. A 9 says retain control I do think I could get it down on the ground eventually but not anywhere near where you want it.

I have no comments on the feel or the sensitivity.

Pitch - nothing stands out.

Initial response - certainly predictability was poor near the ground when I tried to be accurate and quick with the airplane.

Pitch roll harmony - was not a problem. I could not develop any special pilot inputs, certainly it would be nice to think of some but I couldn't get the airplane down without overcontrolling it. There was a tendency to PIO and it was clearly a combination of flight path, pitch airspeed control went to pot right near the ground because I had to abandon the throttle just to try to salvage the sink rate and attitude.

Approach performance - down to 25 ft was not too bad, however, the flare and touchdown was very poor. Tendency to float, overcontrol in pitch, gets serious concerns going about getting down on the ground with the right speeds and attitudes.

The landing was the worst by far.

Turbulence - crosswinds - not a factor. The gust was a factor and saying in a good sense it was a good task it did disturb it near the end, it made you have to get in and correct the sink rate aggressively and that is where things deteriorated rapidly.

In reviewing the rating - I think it's still what I said, it's controllable but you cannot do the job and controllability is in question. I would be

worried about hurting myself on occasion there I think or the airplane. So I like an 8. I don't think the oscillations were divergent but initiate abrupt in tight maneuvers did cause oscillation, I think it's a 4.

FLIGHT 743	CONFIGURATION: 8-3-5-1	PILOT: A
DATE: 9/22/83	HQ RATING: 3	PIO RATING: 1

PILOT: Comments on the first evaluation. It's controllable and clearly I could achieve adequate performance. I believe it is satisfactory without improvement. The first one was near perfect I felt like I was a little lucky to squeek it on, I don't know what that is all about. I'm getting some feed-back.

The second one it dropped out a little bit because I put in a big power change but I really think that I have good control. I just felt a little or just a touch of unpredictability in the flare as if I had a little bit of a peculiar motion but I certainly did achieve desired performance and for now say it's a 3, just because of that little bit of compensation required. I will talk about it some more.

The feel - no comments there. I did notice for the first time I seemed to have to use the trim that wasn't a problem I got it retrimmed on final.

No comments on the initial response.

The predictability of the final response was good that little feeling of having to work just a little bit to control it was there. If you are talking to me I can hear you - Smith to Berthe.

Special pilot inputs - I felt like I wanted to hold what I had a little bit and be a little careful near the ground but I think I could handle it well not chance to PIO.

Airspeed control was good.

Approach performance - no problem.

Flare and touchdown - I thought there was just a slight tendency to float but not a problem. I just had to be a little careful right near the touchdown.

The landing was slightly more difficult.

Effects of turbulence - crosswinds and gusts were not a factor.

The good features - were that I could program the trajectory, my pitch control and my throttle in a natural fashion and get the performance without very much

work and so I stick with it being satisfactory without improvement and I'll just, Oh, I'm going to back away and say that it's a $2\frac{1}{2}$. I think it's just a little nudge from being whatever I felt there but I think it's a very easily manageable airplane.

The PIO rating - so my rating is $2\frac{1}{2}$.

No oscillations.

No undesirable motions.

The PIO rating a 1.

FLIGHT 743	CONFIGURATION: 8-4-5	PILOT: A
DATE: 9/22/83	HQ RATING: 1	PIO RATING: 1

PILOT: Comments on the second evaluation. OK, this one is controllable, adequate performance is clearly attainable. It's also clearly satisfactory without improvement. I had good negligible deficiencies and I think right now I will give it a 1 for a moment here just to talk about it.

The feel - in contrast with some of the other airplanes I have recently seen it felt a little lighter in pitch but once I got used to it, it wasn't a problem.

The pitch and initial response I thought was quite quick, very responsive initially and it was predictable. You tended to fly with a little dithering right near the ground but you could do it with very small inputs with good predictability.

Pitch roll harmony - no complaints.

Special pilot inputs - just tiny inputs you could just dither the nose up to where you wanted it.

No tendency to PIO.

Sensitivity was good.

Speed control - because I was confident in pitch I had lots of time to do that so it was good.

Approach performance - no problems there.

Flare and touchdown - I had very good predictability you could especially control the sink rate very well and the interesting thing to me is that the whole approach from the offset on down seemed very easy in otherwords I could get on the trajectory down to the ground. Get the airplane going down hill and continue down hill in a nice linear fashion even with the gusts coming in, take care of that and I just had a feeling of predictability all the way down, including touchdown. So that landing and approach were equally easy.

The turbulence gusts crosswinds were not a factor.

The good feature - very positive control, it seemed a little on the sensitive side initially but I think that was in contrast to some of the others I have

seen so I found that I could do the job with confidence.

It's clearly satisfactory - and I will express that by saying that I think it's excellent, highly desirable and I will stick with what I said it's a 1, and so is the PIU rating.

FLIGHT 743	CONFIGURATION: 8-1-5-1	PILOT: A
DATE: 9/22/83	HQ RATING: 2	PIO RATING: 1

PILOT: Third evaluation. It's controllable adequate performance is attainable, it's satisfactory without improvement - I think it's a 2.

Force displacements - no problem there.

The sensitivity - was okay it seemed heavier and less responsive than the previous one but was very predictable - reasonable initial response and predictability of the final response was good.

No special inputs. Again, instinctively you can uniformly coordinate the wheel and throttle and come down and control the sink rate in a nice proportional fashion coming to the ground, which makes life easy.

Approach performance was good.

Flare and touchdown - entirely predictable. No difficulties there.

Approach and landing were equally good.

Turbulence crosswinds - not a factor.

Good features - predictable, satisfactory, comfortable airplane. 2.

FLIGHT 743	CONFIGURATION: 4-3-7-1	PILOT: A
DATE: 9/22/83	HQ RATING: 4	PIO RATING: 1

PILOT: Fourth evaluation. I think it's controllable, I think you can achieve adequate performance. In fact I could achieve desired performance. On the first approach I would have said it had some minor but annoying deficiencies it's for a 4 and on the second one I would have said it's a 3. So let me just leave it at that and I will talk about it and make a final decision.

No complaints about the feel system.

The initial and final response seem to be well behaved. Nothing spectacular but it was predictable in the pitch.

Special pilot inputs - I thought on the first one I floated and had to ease it onto the ground and sort of spike it on rather than smoothly integrated the pitch and the throttle to get a nice smooth touchdown. The second one I did a little better.

The speed control - it's good.

Approach performance - no difficulties there.

The flare and touchdown - I did notice some tendency to float on the first one whether I compensated on the second I don't know, but I did better on the second. These are not big problems just small problems. It was a fairly well behaved airplane.

The landing - slightly more difficult - turbulence in crosswind and the gust was there but it didn't seem to really upset my task a whole lot.

The good features - it was a pretty solid airplane. Predictable.

Reviewing the rating - I think that adequate performance is attainable, I know I did achieve desired performance. I'm going to say it's a 4 because the deficiencies are minor but annoying and I guess I'm weighing my first approach more than my second and thinking about some of the other I have flown so I think it just had a little tendency to float which required a little bit of compensation there. In terms of the PIO rating, I didn't see any oscillations.

Undesirable motions - no, so it's a 1. Just a little floating tendency was my only complaint.

FLIGHT 744	CONFIGURATION: 8-5-5-1	PILOT: A
DATE: 9/23/83	HQ RATING: 4	PIO RATING: 2

PILOT: The comments - it's controllable, I think you could achieve adequate performance, in fact, I think I could have achieved desired, but I had some problems that I consider warrant improvement so right now I would say that I achieved desired performance with some minor problems, so it's a 4.

On the rating and the comments - the feel - nothing noted in the feel that I wish to comment on. Sensitivities - no complaints there.

Initial response in pitch - the predictability seemed good to me although when I got down to the ground there was a little bit of an unexpected touchdown, a little lack of control there that I have reflected in the rating that I gave it.

Airspeed control - was good

Approach performance - nothing there.

The flare and touchdown - I did feel a little tendency to hunt and couldn't control the sink rate in a nice smooth fashion and the result was - I don't think we made hard touchdowns they were just slightly unexpected in the sense that I didn't get it right when I wanted it. I touched down in the desired area I believe.

The approach and landing - the landing was a little more difficult.

Turbulence - we did have a crosswind that was real on the first approach which made life a little more difficult. Turbulence was not a factor.

Good features - I did feel confident about being able to get the airplane down it was just a question of fine precision wasn't quite there near the end.

So overall rating - I thought it was, I could do the job and achieve adequate performance but not satisfactory. I got desired performance and I didn't work all that hard so I think a 4 is appropriate.

In terms of the PIO rating - I think I did see some undesirable motions I think the task was compromised in the sense of not being able to get desired performance, so I say it's a 2.

FLIGHT 744	CONFIGURATION: 8-3-5	PILOT: A
DATE: 9/23/83	HQ RATING: 7	PIO RATING: 3

PILOT: These are the comments on the second evaluation. It just really felt like a strange airplane to me, it felt that I was out of phase with it even if it was just down wind. I had a strong feeling of apprehension with the airplane, although the first one I didn't really get into a big oscillation but I could see myself just holding back and not wanting to get in there and I tended to float, I didn't want to push forward. The second one I could feel the tendency to balloon and oscillate and despite the fact on the second one I said I was going to go see it and sort of mix it up and go and fly it down there I just couldn't bring myself to do it. I just felt apprehensive about the airplane. So I think it's controllable, but I don't know where I would touch down likely not too far from where I was supposed to but I couldn't touch down the way I wanted and the last one was very uncomfortable to me because I hit the ground and I couldn't bring myself to put in a quick enough input to try and stop it for whatever reason that you sense. So I didn't like it and I don't think I would consider it adequate performance even though I touched down in the desired area I was very uncomfortable with the airplane. So I think I am going to give it a 7 because of that.

The feel - I did notice one thing and I noticed it the other day and didn't comment on it. I tend to be coming out of turns and really noticing that on the last stage of the turn I have to use a lot of nose down trim. It's not a big event but I notice myself trimming more.

The pitch - It did not feel predictable to me it felt strange so I can't identify anything specific with that but the whole thing felt a little unnatural to me.

Special piloting inputs - I didn't develop any in the two approaches I had. I thought there was a tendency for what I call a PIO, that is sort of a combination flight path and pitch.

The approach performance - this characteristic even bothered my approach performance a little bit so the flight path corrections I had to pay more attention to.

The flare and touchdown was the problem. I had a tendency to float, a reluctance to get in and do something about it. I seem to on the last one, the

first one I didn't get the power, on the second one I did and I just wasn't correlated my two hands because of the nature of the airplane.

Landing was the worst.

Turbulence - the crosswinds were not a problem, gust was an effective task element. The good features - I don't remember any.

Overall rating - I just think it's a 7 and not so much on the performance but on my apprehension and my inability to get in there and do anything about it.

I didn't see any divergent oscillation. I did some oscillations, undesirable motions and I do think they compromised the task. So that would be a 3.

FLIGHT 744	CONFIGURATION: 8-3-5-1	PILOT: A
DATE: 9/23/83	HQ RATING: 3	PIO RATING: $1\frac{1}{2}$

PILOT: Third configuration - It's controllable, adequate performance attainable, desired performance so it's satisfactory. I just couldn't be as quite as precise as I wanted to be right in close, there's a little bit of oscillation in flight path so I think that that is a 3 right now.

Second approach - landing was much better than the first. I think that's generally true when you get to know a little bit about the airplane so I knew how far I could trust it I felt fairly confident.

No comments on the feel.

The pitch - seemed good initial response and predictable with slight deterioration near the ground and my flight path control I can't separate that totally from - I don't know if it's flight path or pitch but a little bit of hunting right near the ground.

Airspeed control was good.

Approach performance was also good.

The flare and touchdown - Just a little problem of being perfectly natural right near the ground and comming on through with a constant correction to get down and hunting right near the end but I could as I did on the second one, control the sink rate quite accurately and the touch down point so I think the landing was a little more difficult than approach but not significantly so.

Turbulence was not a factor.

Good features - it was an airplane I had confidence in being able to touchdown where I wanted to with the sink rate that I had predicted. So reviewing the rating I stand with what I said, I could certainly get the job done. I think it's satisfactory. I just back off from being a 2 because of those comments that I made and I would say mildly unpleasant deficiencies, minimal pilot compensation are good words for it, so a 3 is the rating.

Undesirable motions - I hate to say - I would give it a $1\frac{1}{2}$ and that's fair. Just a little bit of that hunting but I don't really think it's the category of undesirable motions.

FLIGHT 744	CONFIGURATION: 8-2-5-1	PILOT: A
DATE: 9/23/83	HQ RATING: 7	PIO RATING: 4

PILOT: Comments on the fourth configuration. I was somewhat confused on the first case, I wasn't sure whether I had just made a good one look bad by not doing it right or made a very bad one look good. The second approach seemed to indicate the latter was the case. The airplane tended to have a flight path PIO and did not or would not rotate the airplane, I couldn't get it rotated fast enough so I tended to overcontrol the flight path. I think it's controllable, adequate performance - for the moment I will say yes I could achieve adequate performance but it would be a 6 and I will likely change that based on the last one.

The comments - the forces displacements - nothing there.

The pitch roll sensitivity - no comments.

Initial response in pitch seemed to be slow and a tendency to overcontrol so the predictability is poor. Again, I sometimes have difficulty separating out what's flight path and what's the pitch attitude but in any event I tended to especially on the last one get into an overcontrol situation in terms of flight path and ended up cycling towards the ground knowing that I was going to hit formerly but I couldn't get the nose rotated fast enough or wouldn't put in the large enough input to do that. So the approach performance itself I didn't have any difficulties there getting the initial conditions for the offsets in controlling the flight path.

The flare and touchdown - the first one I just about touched down, came within inches and then ballooned up a little bit, it didn't seem very bad. The second was an exaggerated version of that and I thumped down and I am comparing this to the airplanes where I don't have those kind of problems and I don't think this was satisfactory, therefore -

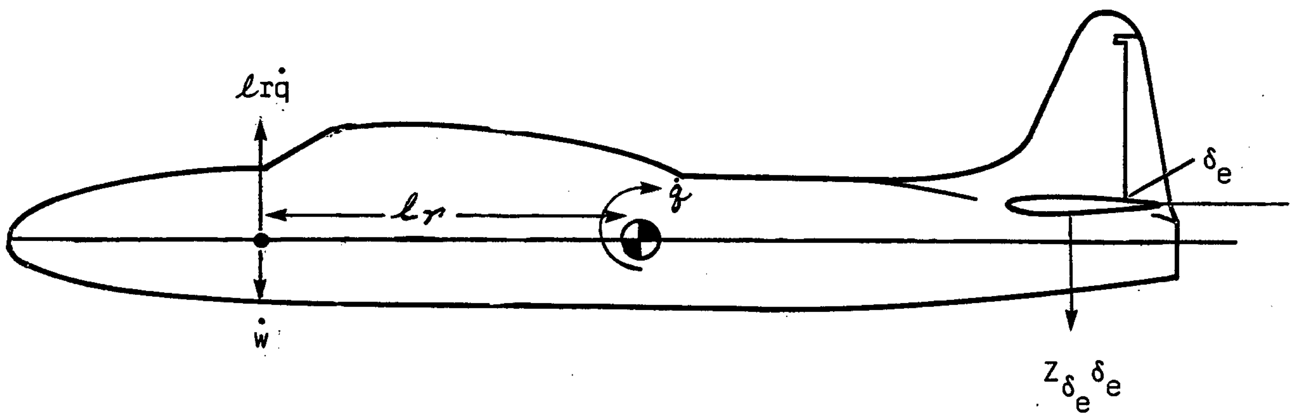
Approach and landing - landing was fairly more difficult. Gust was a good task exciter.

Good features - I don't remember any and I guess the second approach of the two stands out. If we had all day we would likely go back and do it again to see which one. I think I had the same kind of problem with the first one except it was just of a much smaller magnitude. So think I it's controllable - I just didn't like the airplane I guess. My control near the ground was

not good so I'm going to say it requires improvement near the ground the last 20 ft, so the rating is a 7. When I enter the loop near the ground, I don't get divergent oscillations, I get some oscillations which were not divergent, so I give it a 4.

Appendix G
CENTER OF PERCUSSION DERIVATION

The center of rotation (center of precussion) is the point on the aircraft x-axis where the normal acceleration due to elevator lift is balanced by the normal acceleration due to pitch acceleration. The distance, ℓ_r, from the CG to the center of rotation can be determined by the following method:



At position ℓ_r, the normal acceleration $\dot{w}$ is is balanced by the acceleration due to $\dot{q}$. i.e.,

$$N_{z_{\ell_r}} = 0 = \dot{w} - \ell_r\,\dot{q}$$

where:

$$\dot{w} = Z_{\delta_e}(\delta_e)$$

$$\dot{q} = M_{\delta_e}(\delta_e) + M_{\dot{w}}(\dot{w}) = M_{\delta_e}(\delta_e) + M_{\dot{w}}Z_{\delta_e}(\delta_e)$$

$$\therefore \quad N_{z_r} = 0 = Z_{\delta_e} - \ell_r\left[M_{\delta_e} + M_{\dot{w}}Z_{\delta_e}\right]$$

or

$$\ell_r = \frac{Z_{\delta_e}}{M_{\delta_e} + M_{\dot{w}}Z_{\delta_e}}$$

where: $$Z_{\delta_e} = L_{\delta_e} = -\frac{1}{m}\bar{q}\,S\,C_{L_{\delta_e}}$$

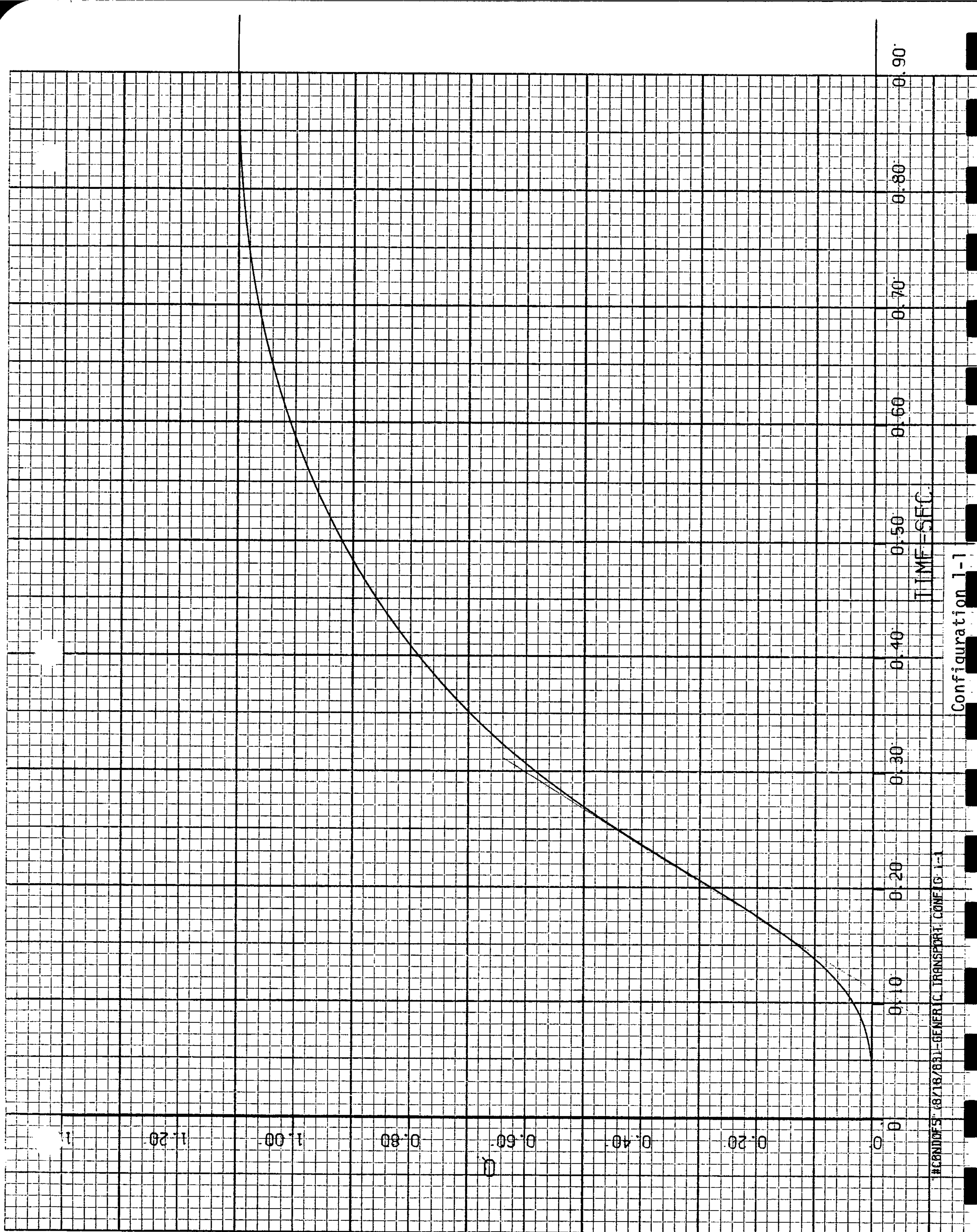
$$M_{\delta_e} = \frac{1}{I_y}\bar{q}\,S\,\bar{c}\,C_{m_{\delta_e}}$$

$$M_{\dot{w}} = \frac{\rho\,S\,\bar{c}^2}{4I_y}C_{m_{\dot{\alpha}}} \text{ (normally quite small)}$$

$$\therefore\ \ell_r \approx \frac{Z_{\delta_e}}{M_{\delta_e}} \approx \frac{I_y}{m}\,\frac{C_{L_{\delta_e}}}{C_{m_{\delta_e}}}$$

APPENDIX H

COMPUTER TIME HISTORIES EXPANDED SCALE FOR TIME DELAY MEASUREMENTS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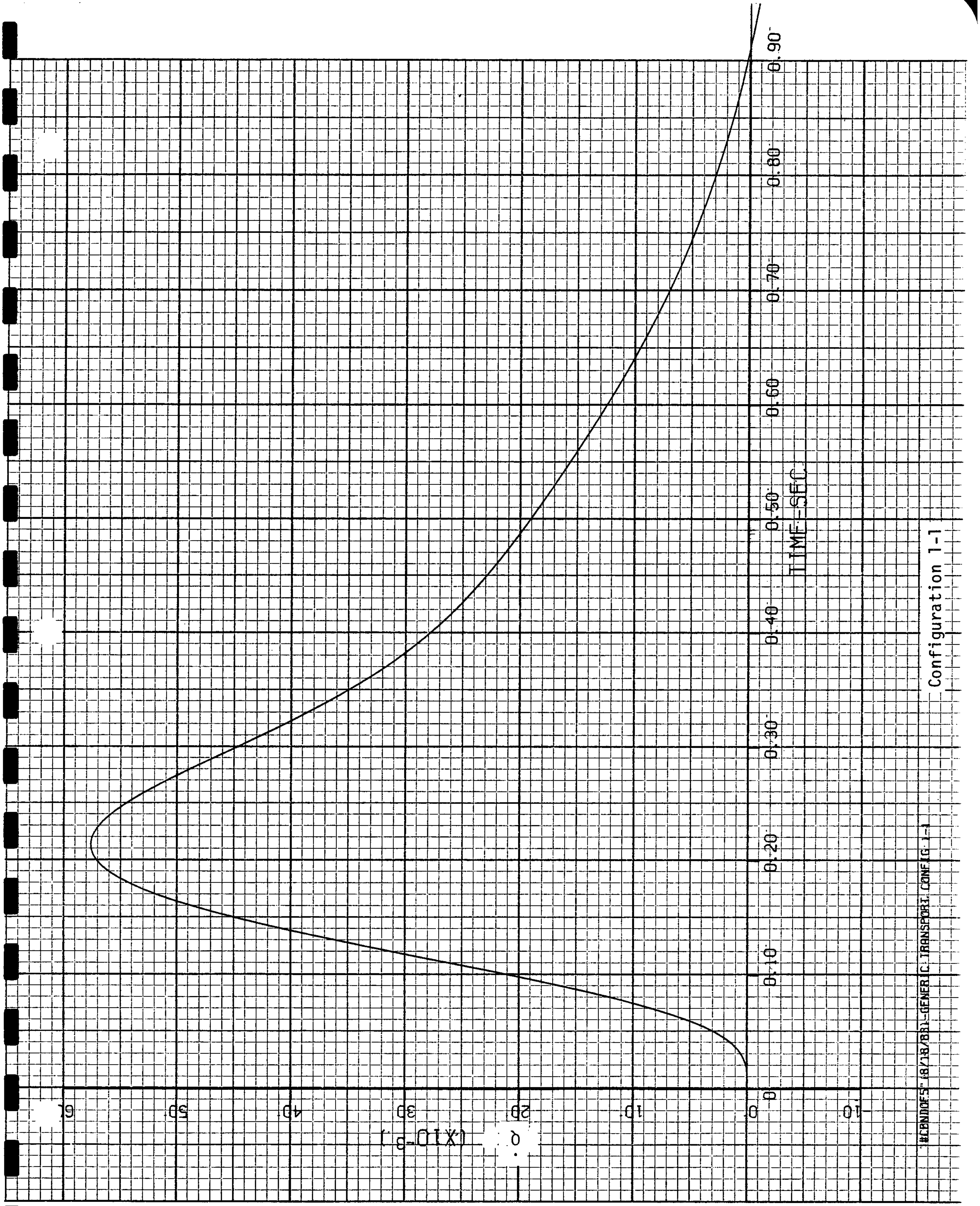
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Q
0
0.20
0.40
0.60
0.80
1.00
1.20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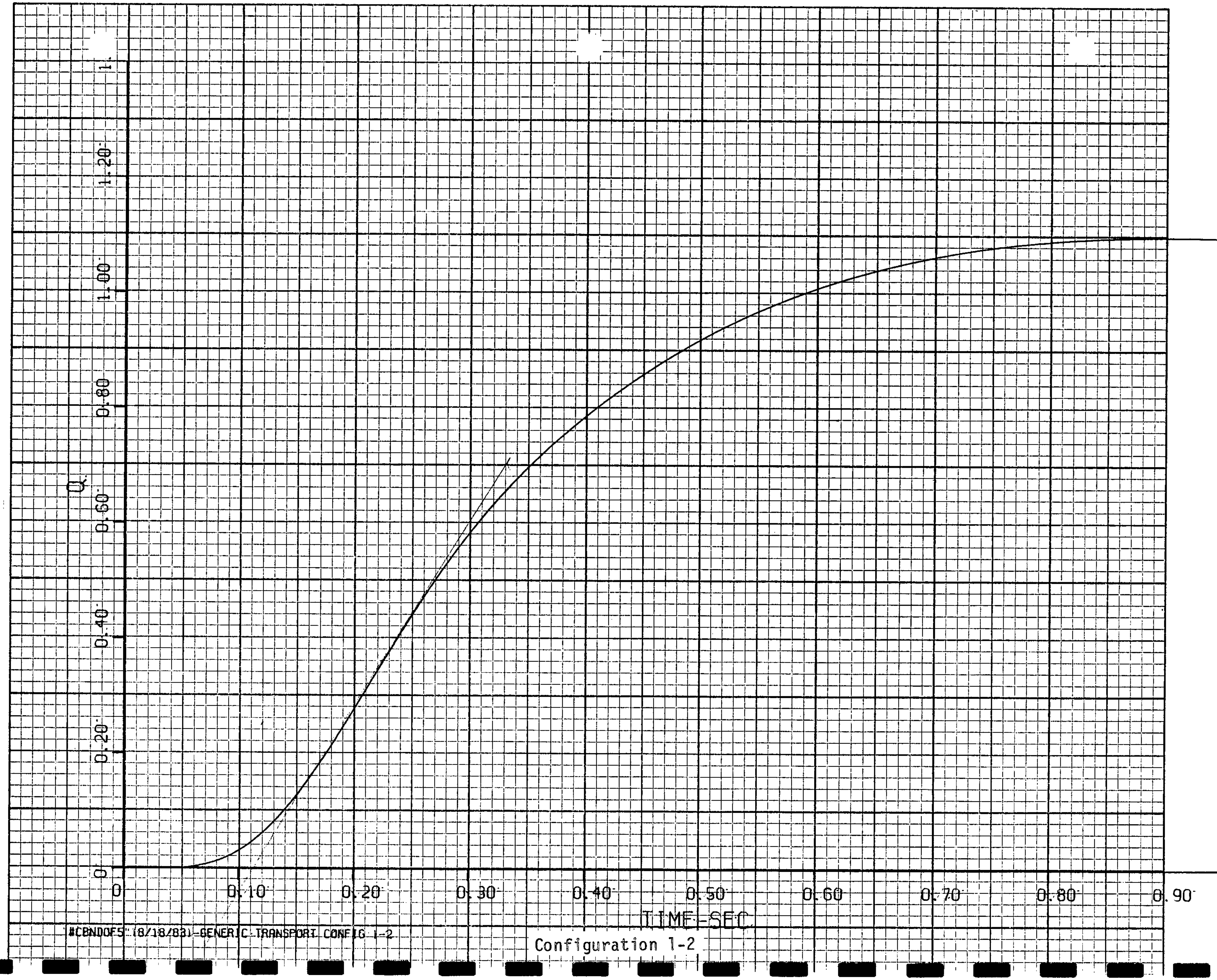

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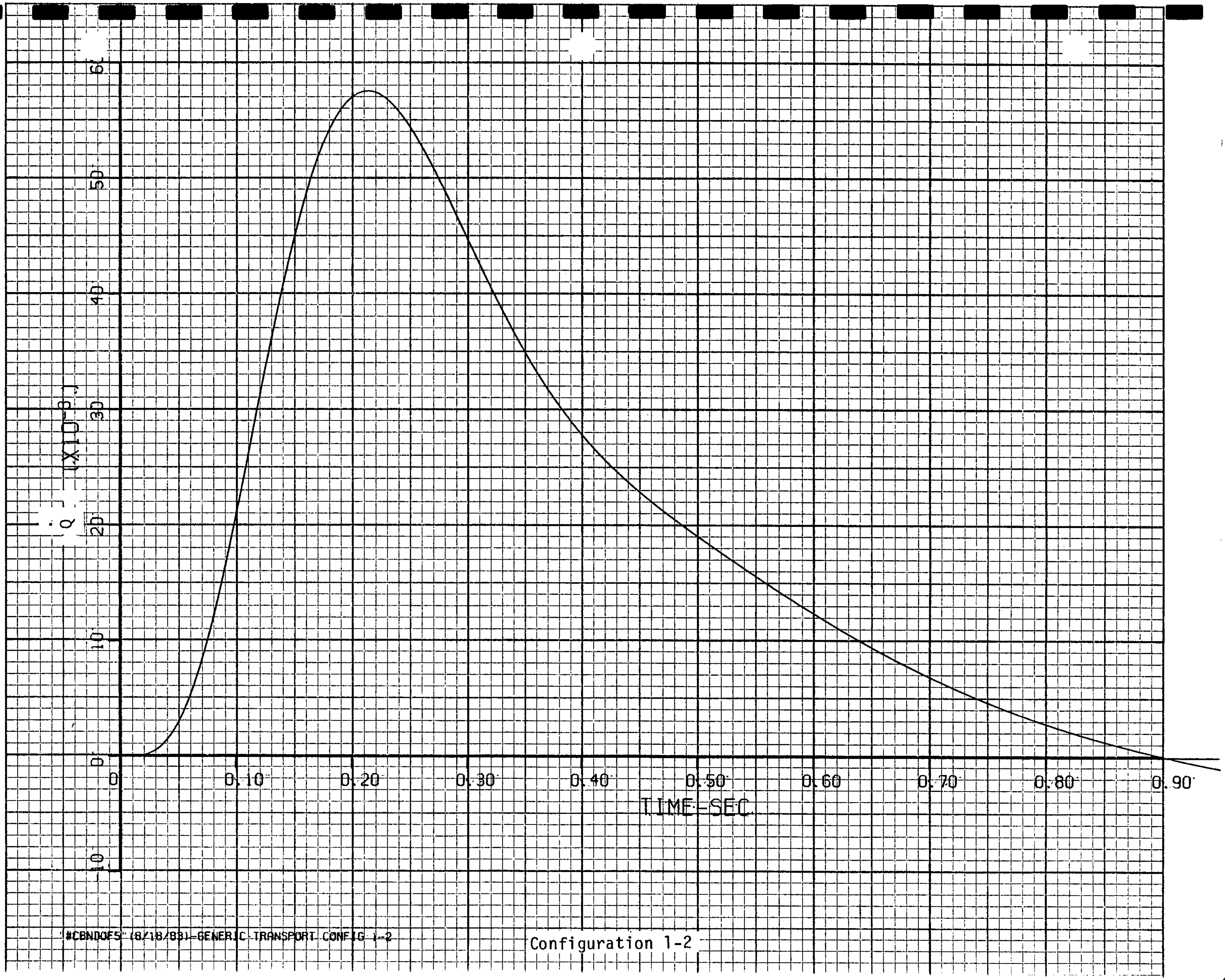
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40
30
20
10
0
-10
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
TIME-SEC
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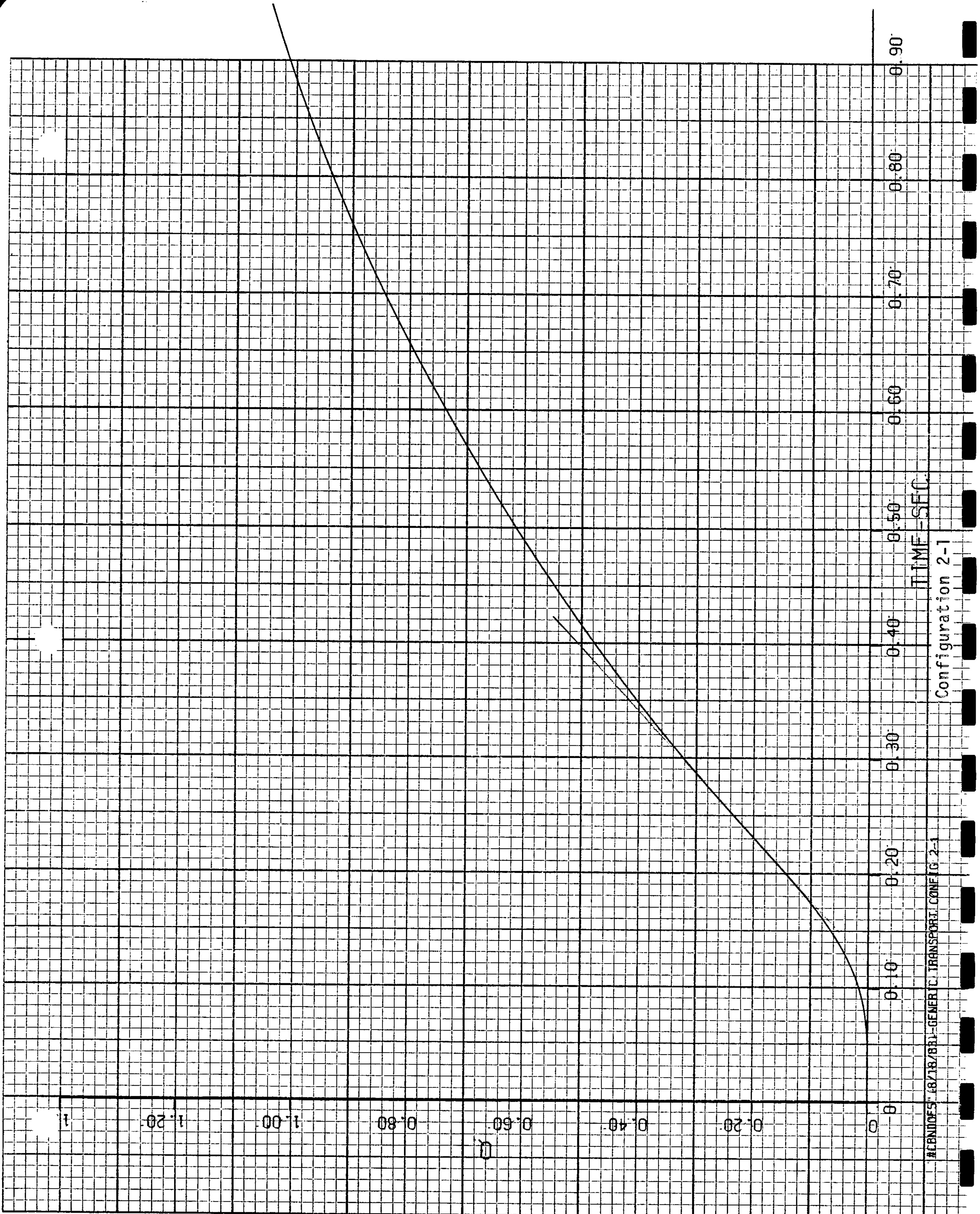
Configuration 1-2



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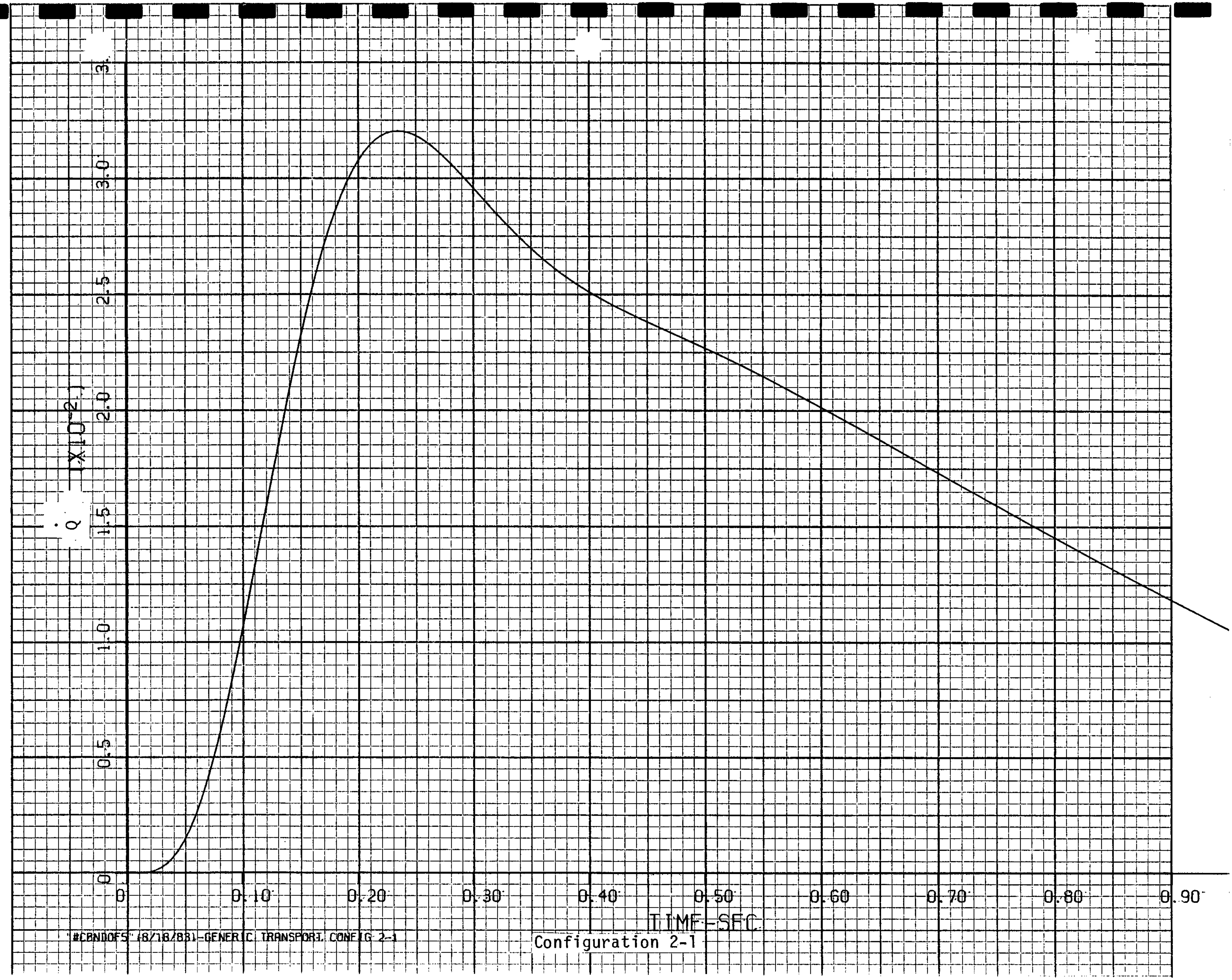

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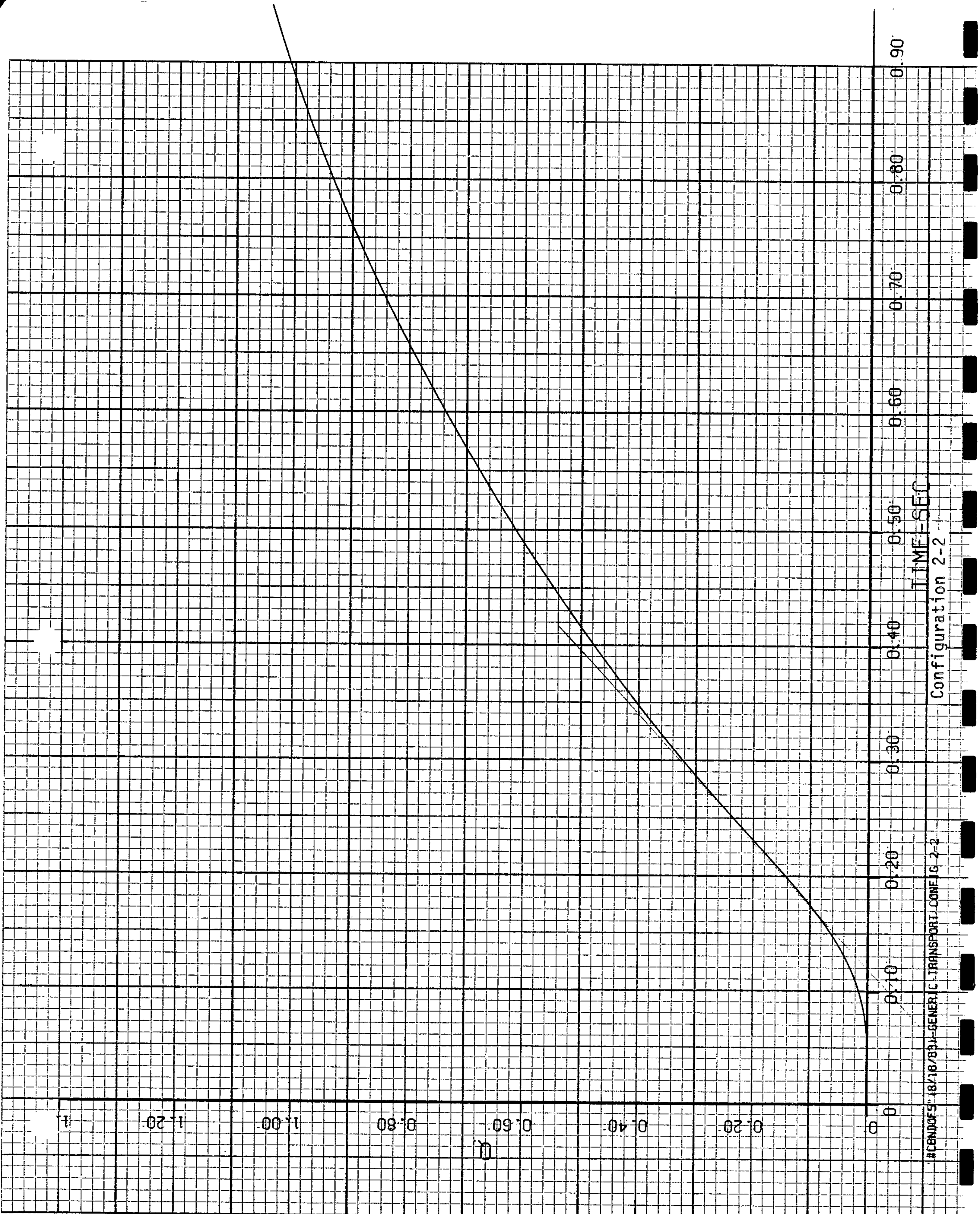

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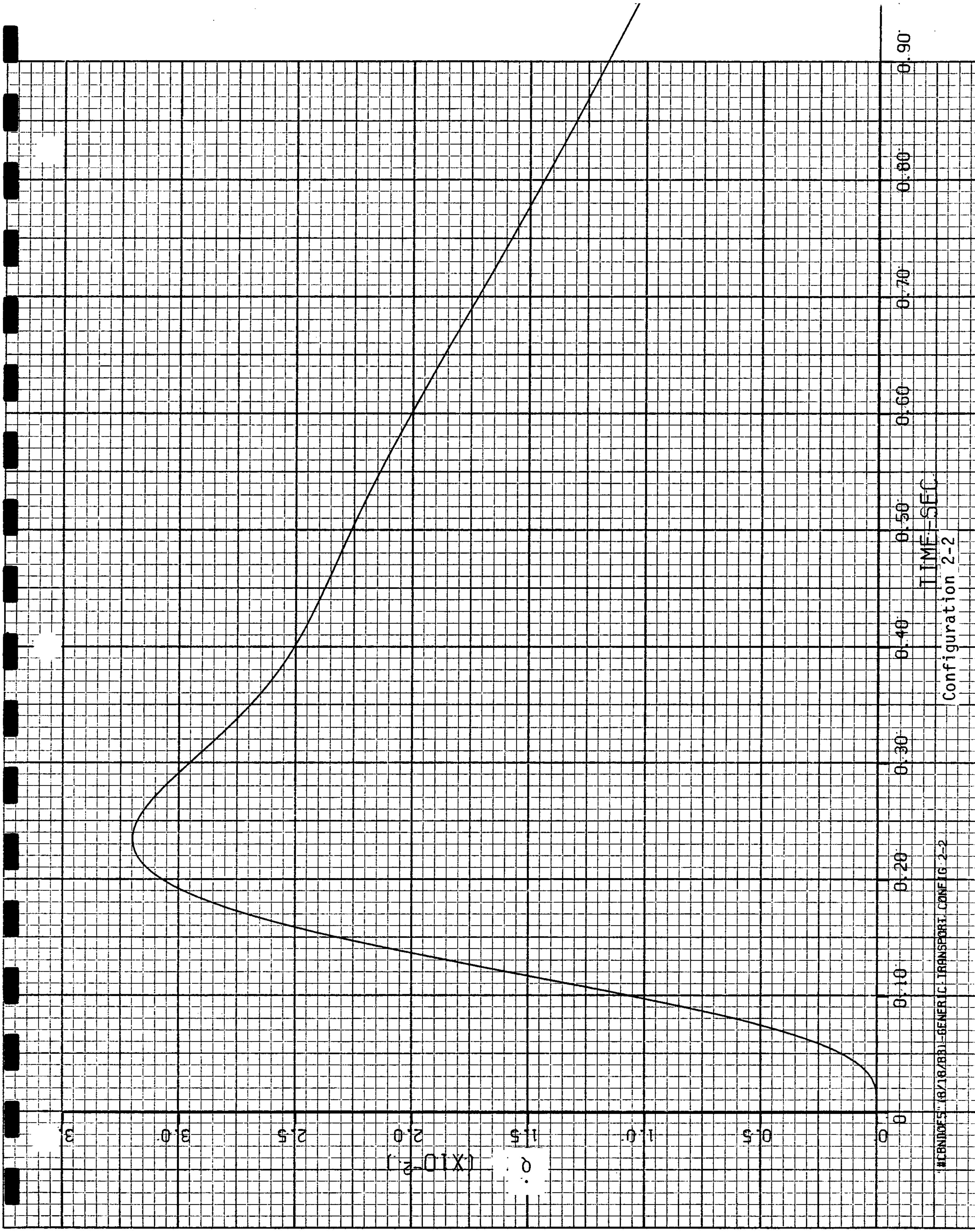
0.80
1.00
1.20



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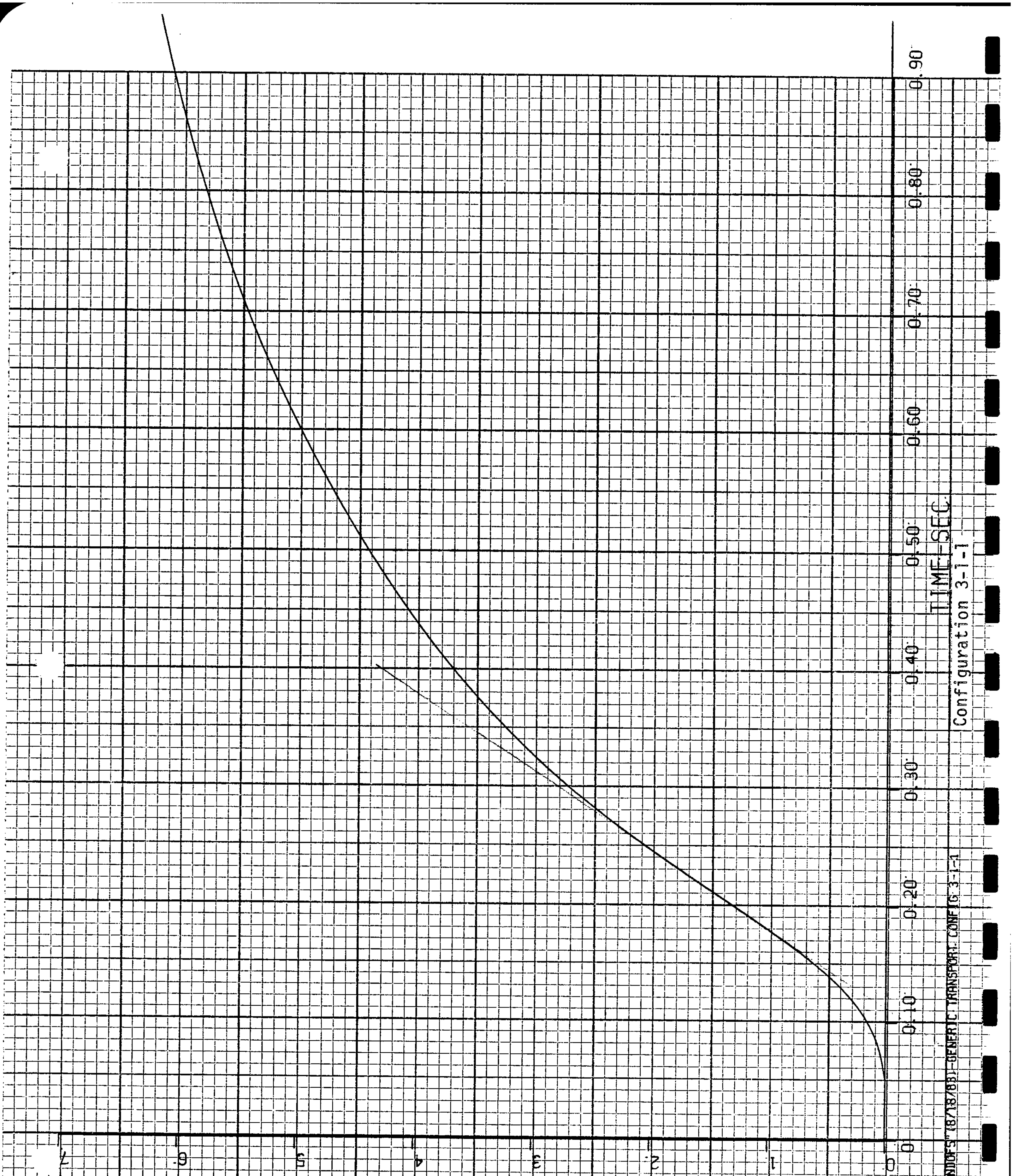
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0.30
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0.60
0.70
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0.90
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1
2
3
4
5
6
7
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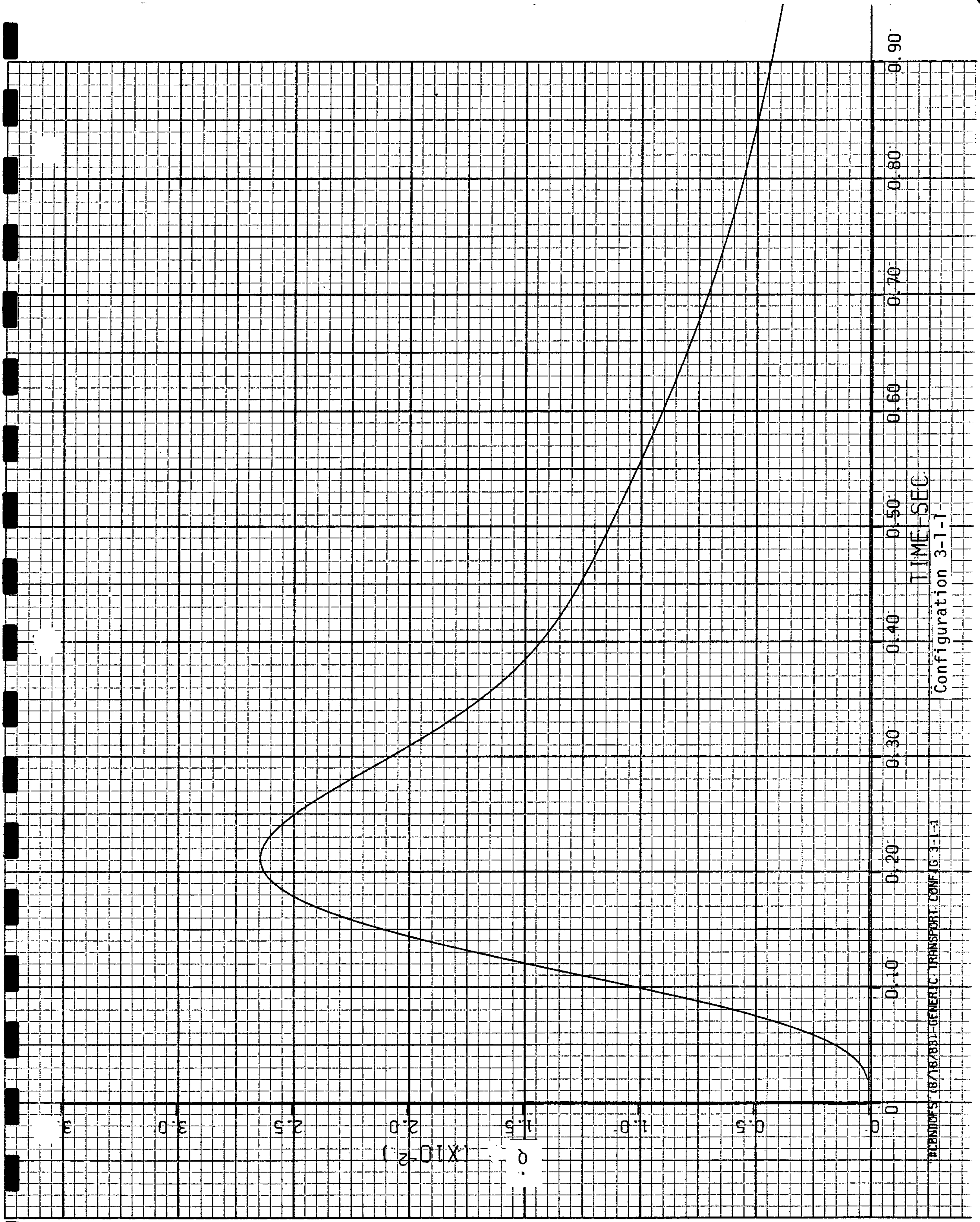
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0.30
0.40
0.50
0.60
0.70
0.80
0.90
TIME-SEC
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1.0
1.5
2.0
2.5
3.0
(X10-2)
Configuration 3-1-1
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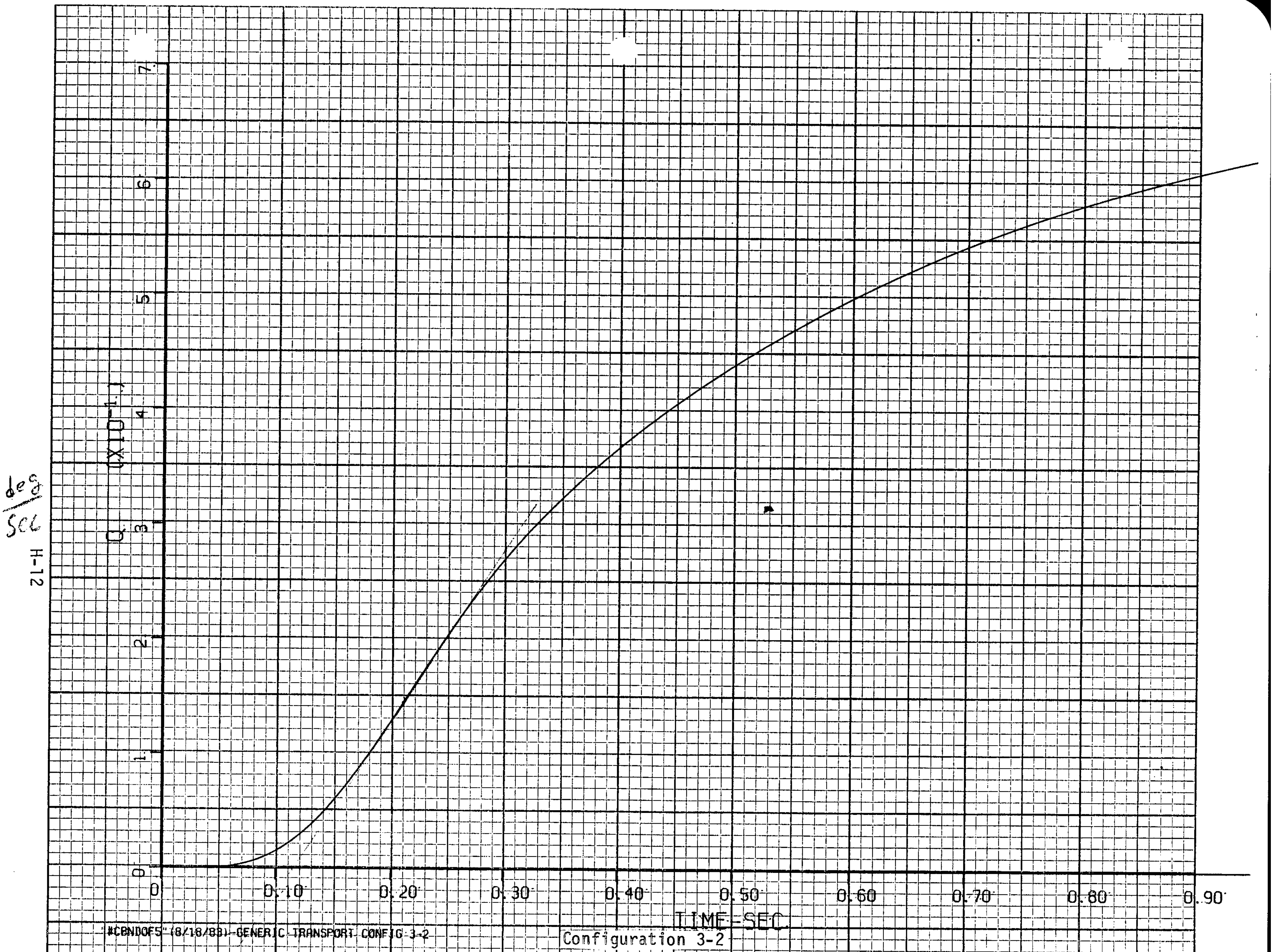

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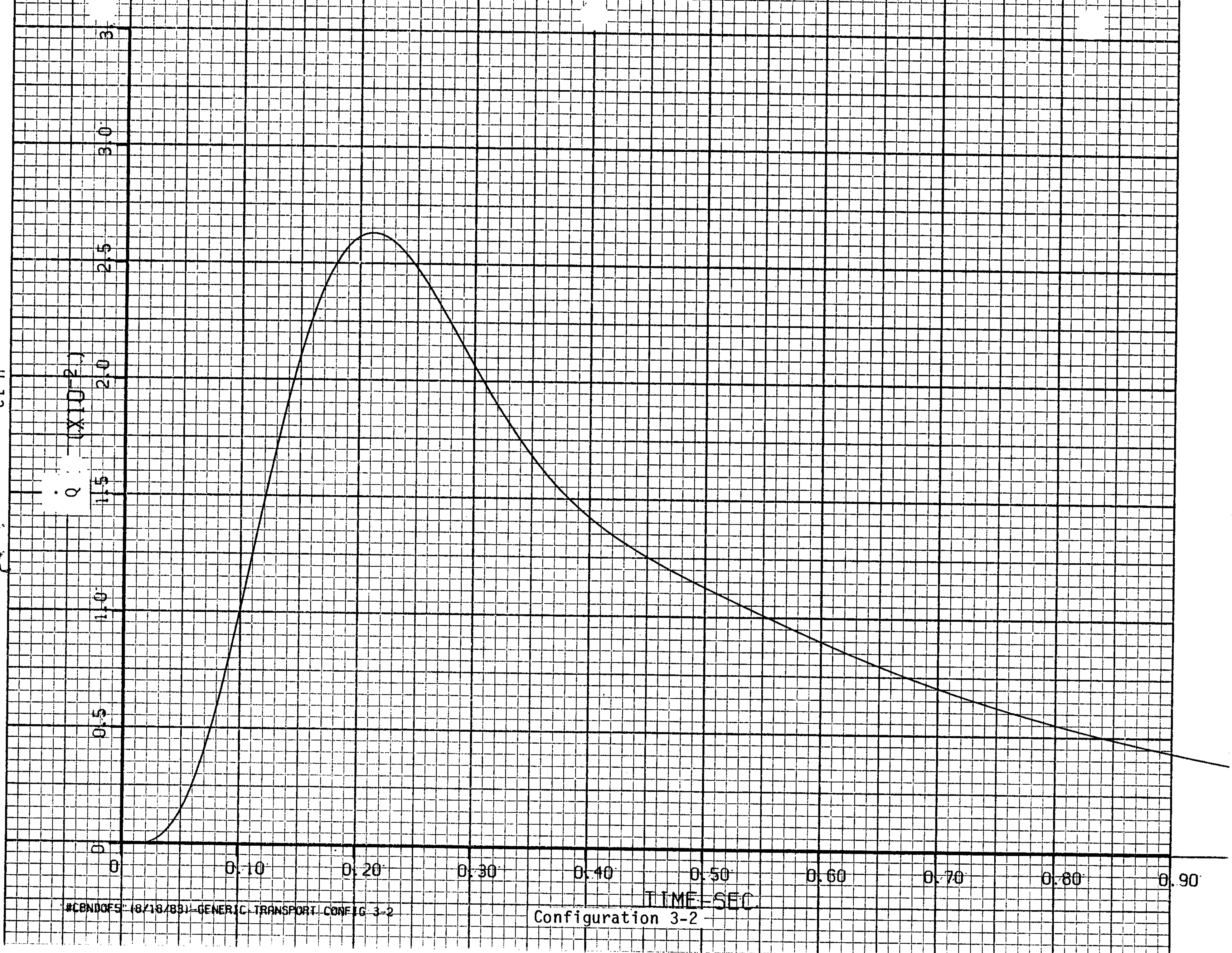

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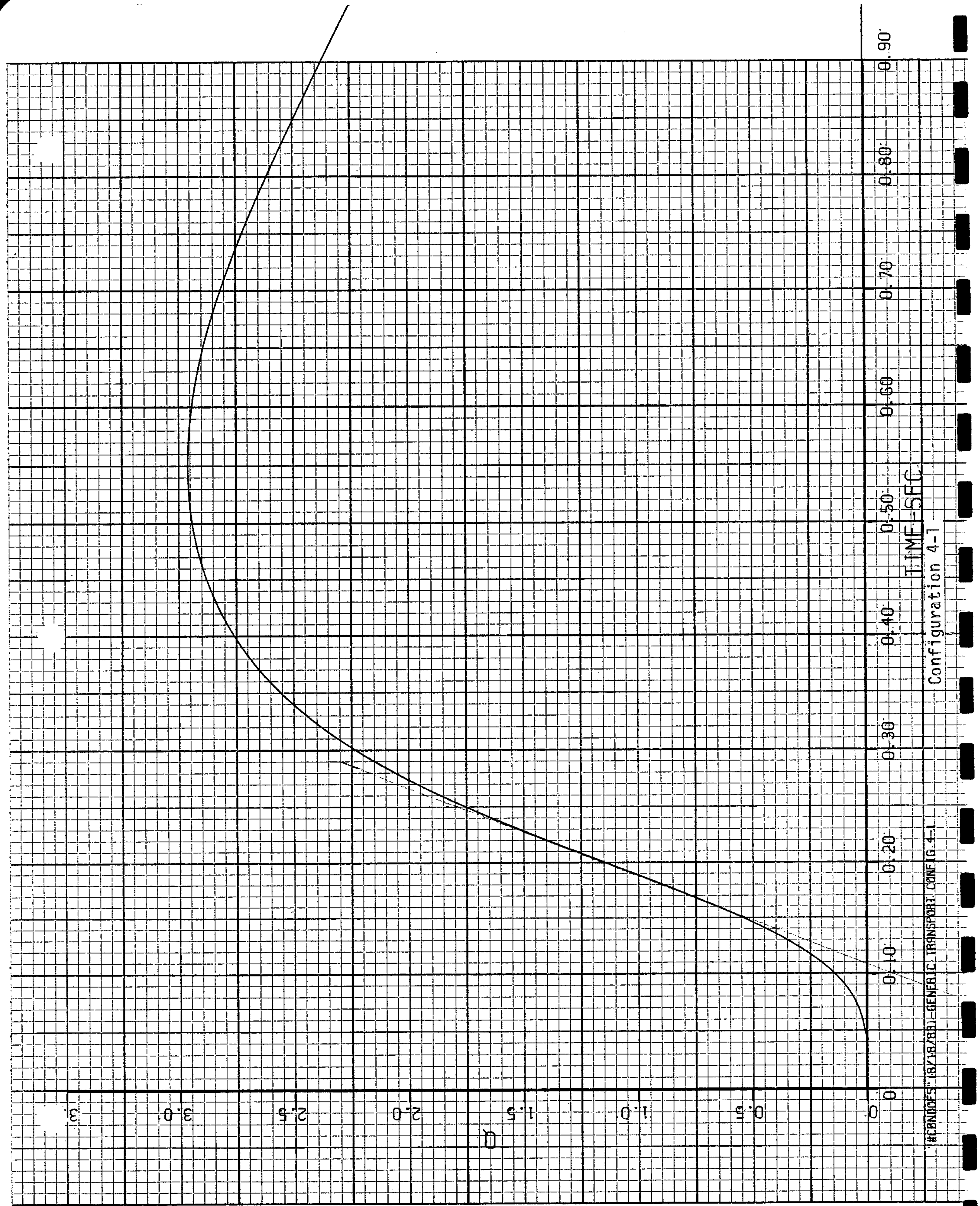

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0.90
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1.0
1.5
2.0
2.5
3.0
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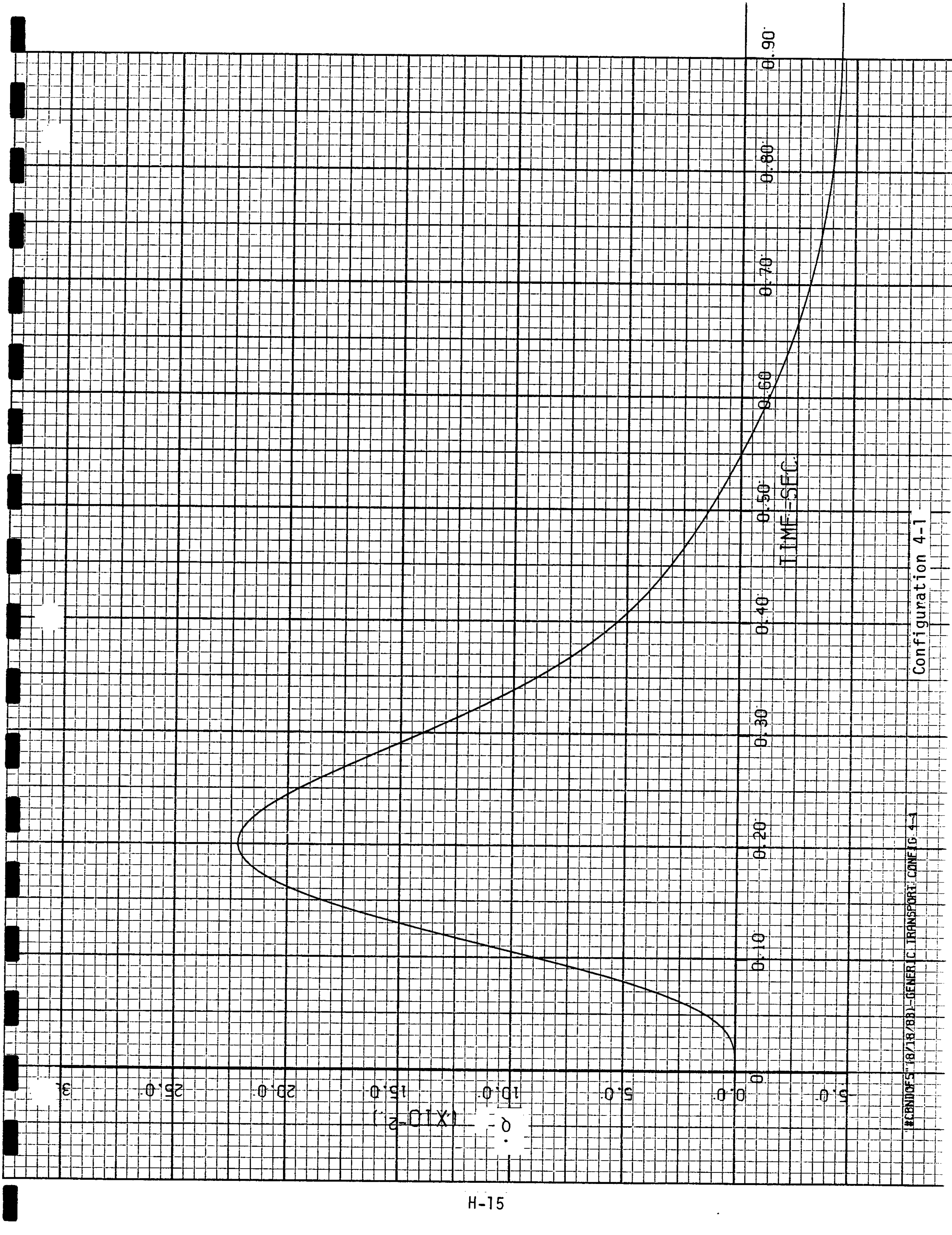
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0.80
0.90
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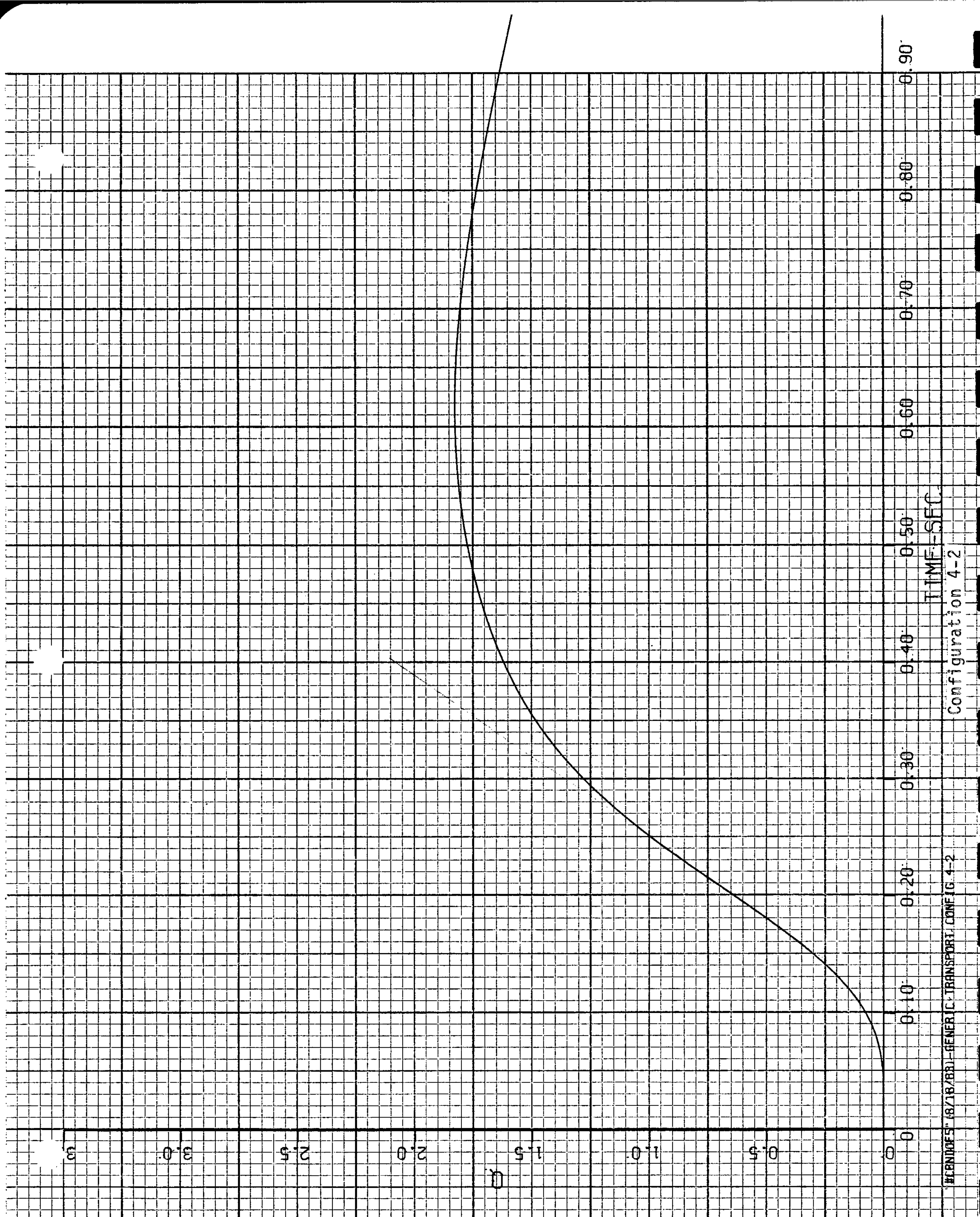
10.0
15.0
20.0
25.0



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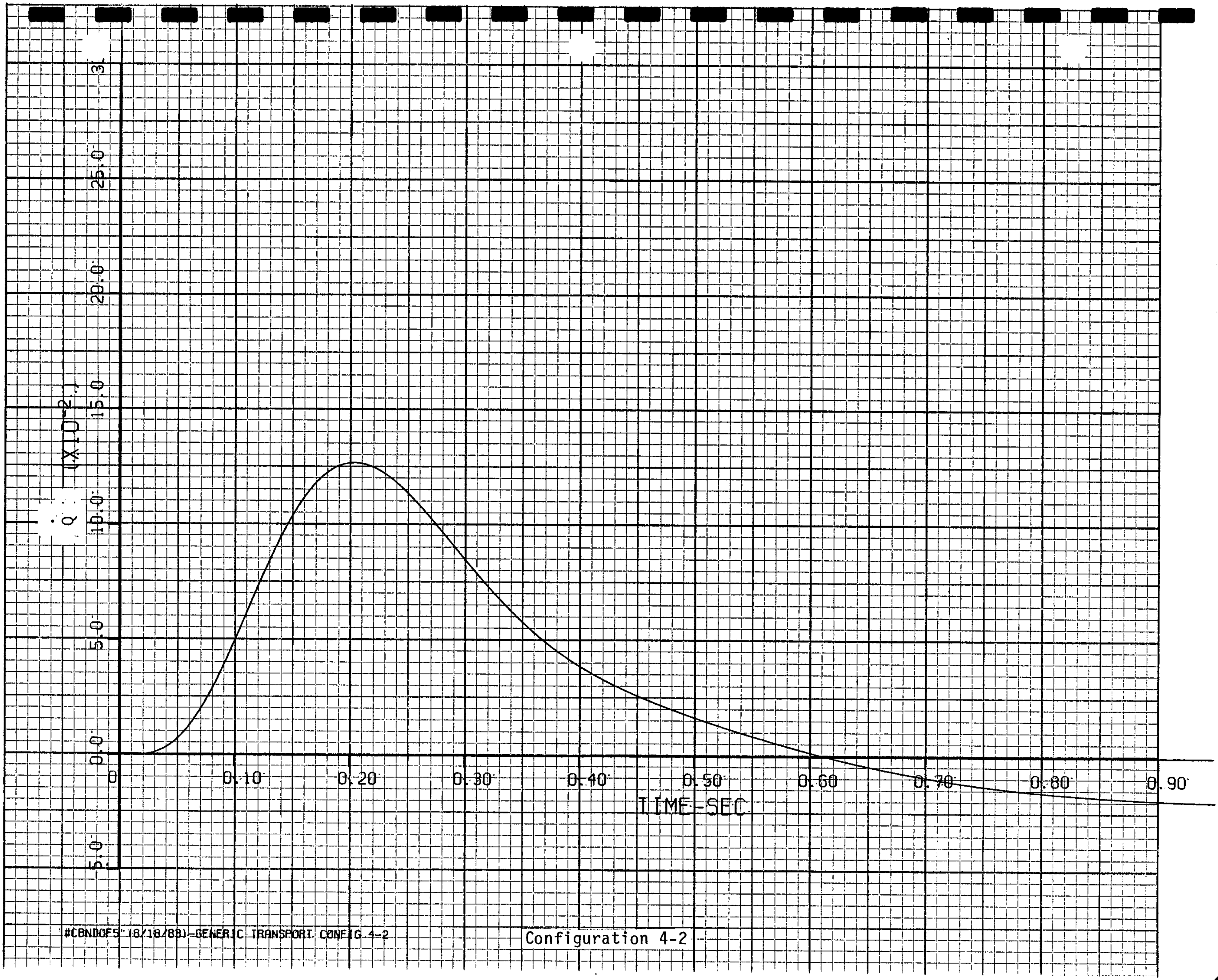
2.0
2.5
3.0
Q



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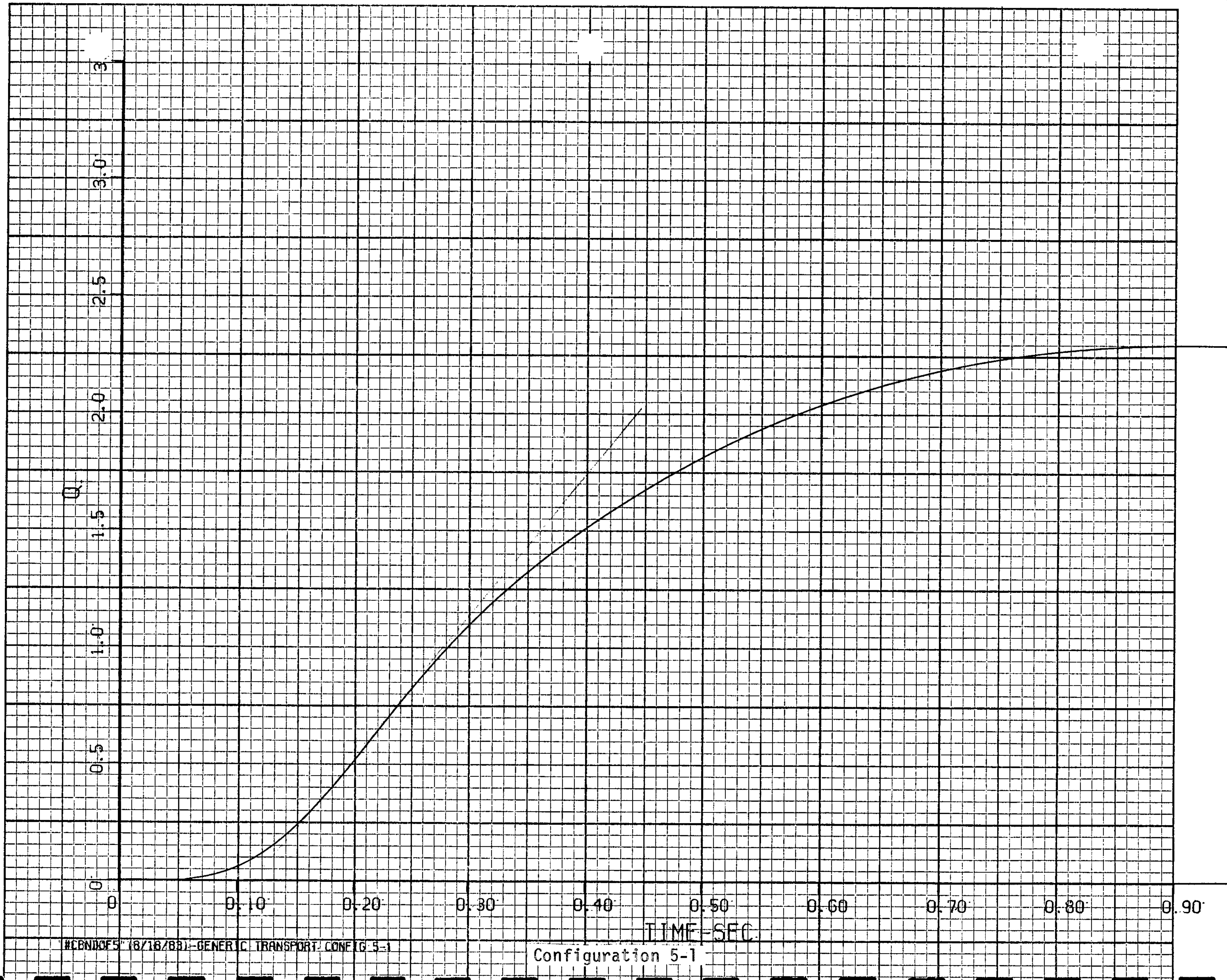

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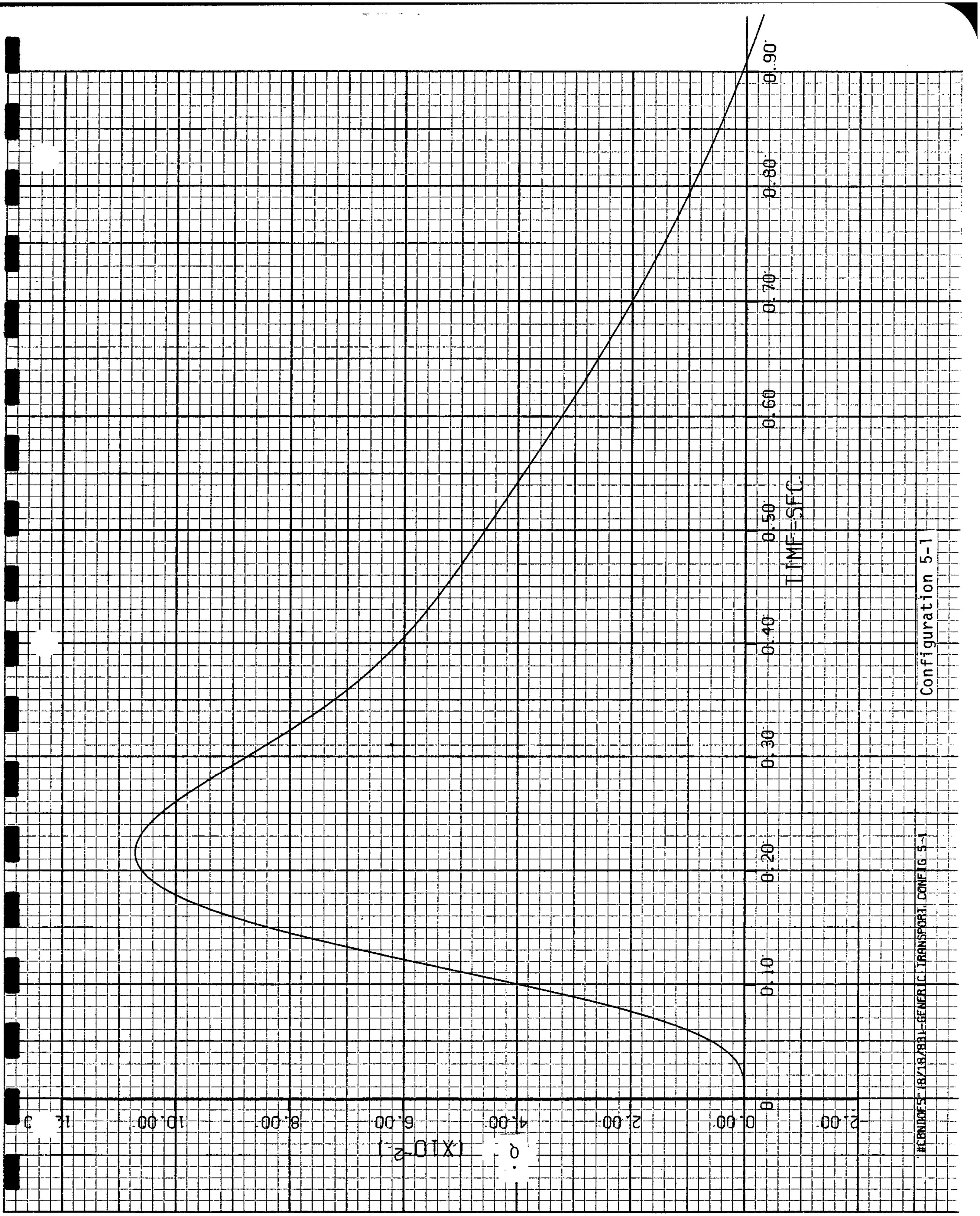

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0.70
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0.90
TIME-SEC.
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2.00
4.00
6.00
8.00
10.00
Q (X10-2)
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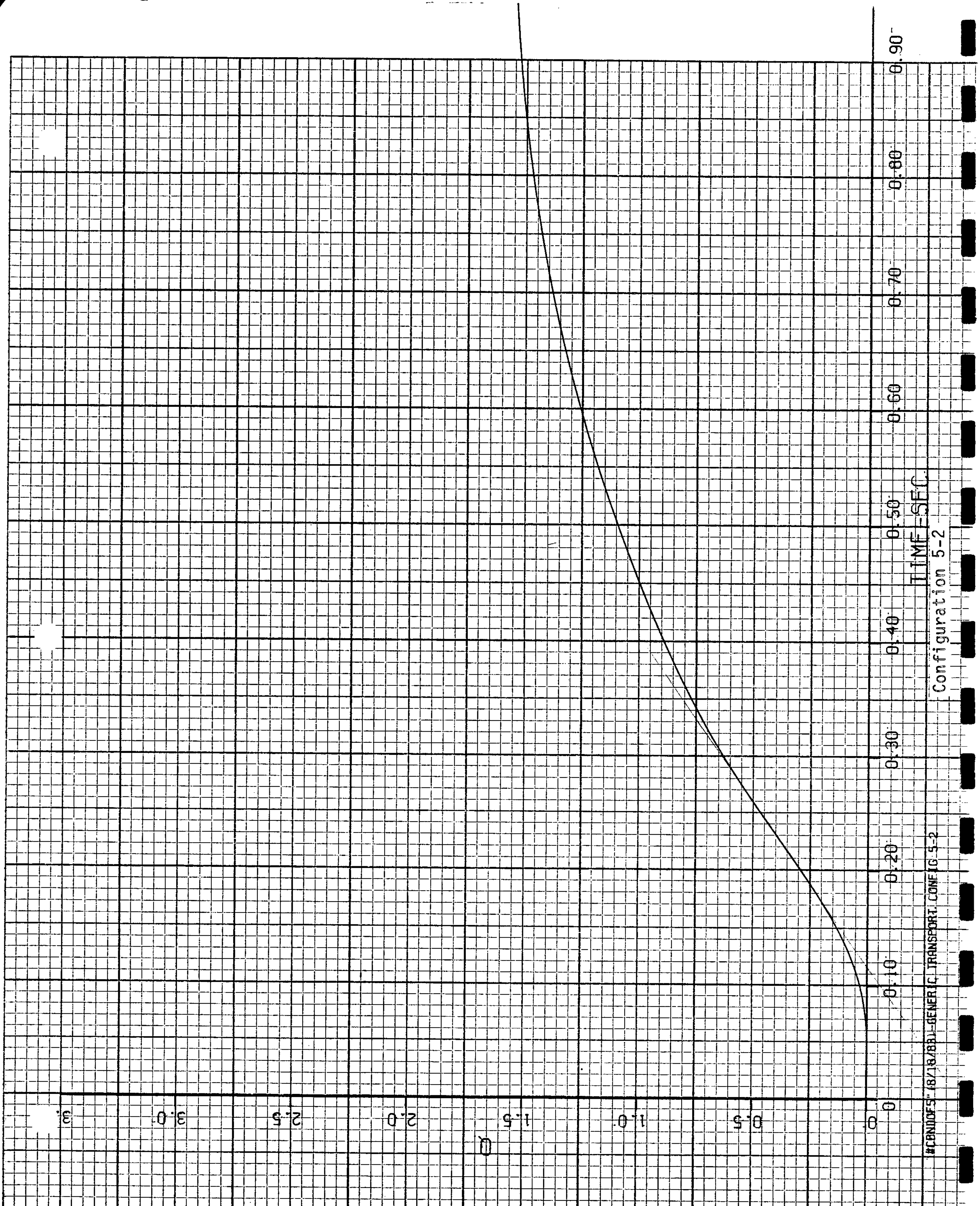

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0.50
0.60
0.70
0.80
0.90
TIME-SEC
Configuration 5-2
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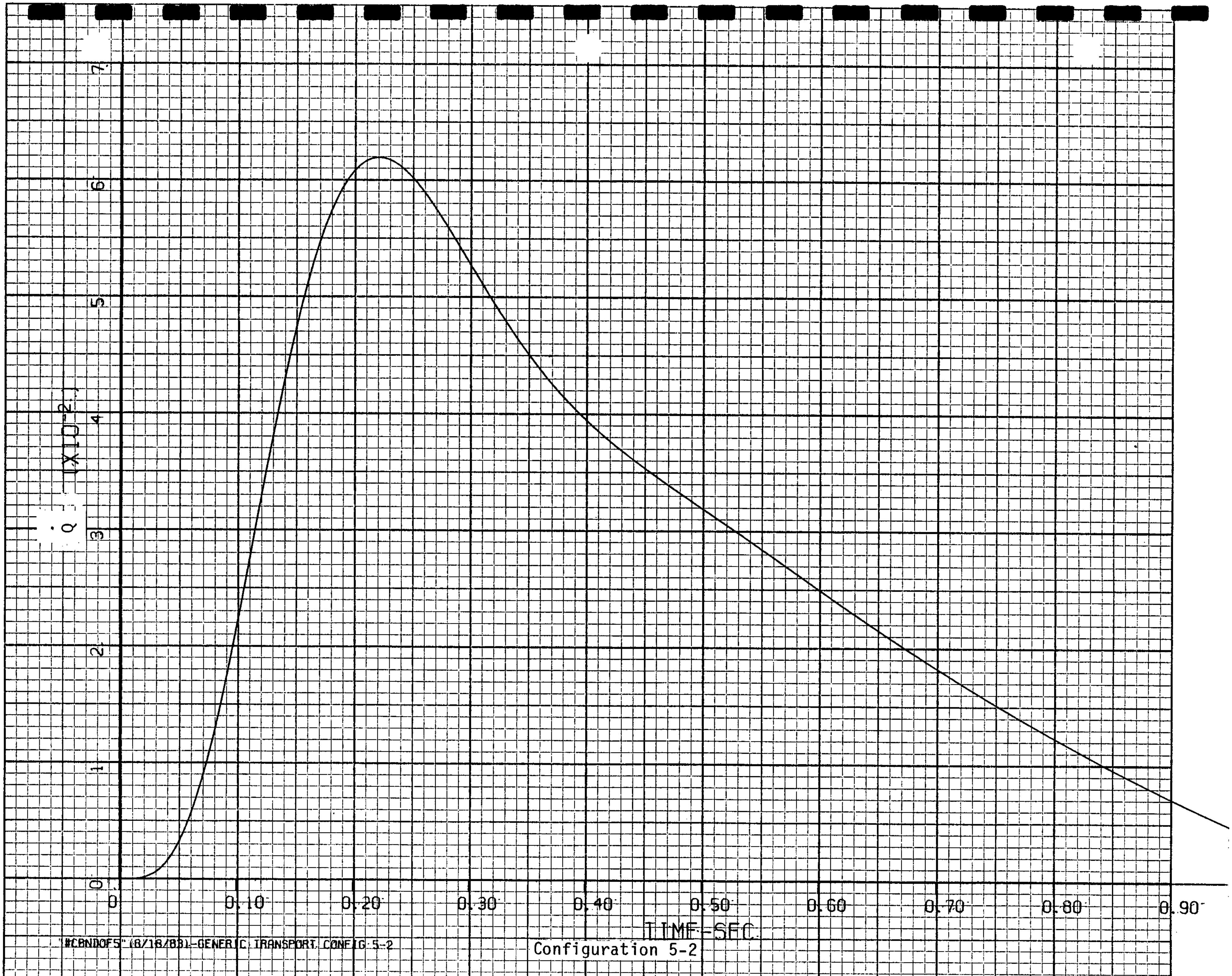
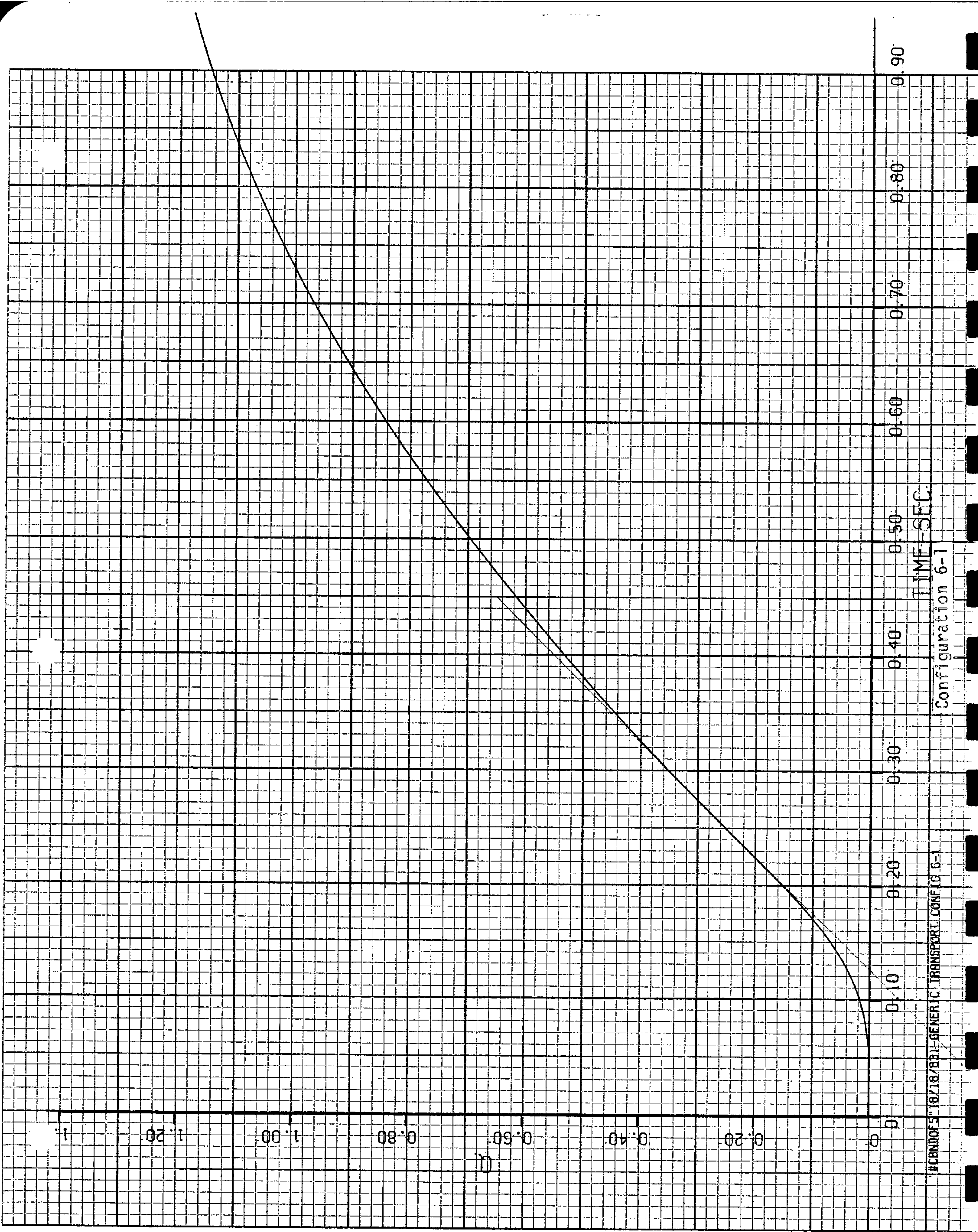
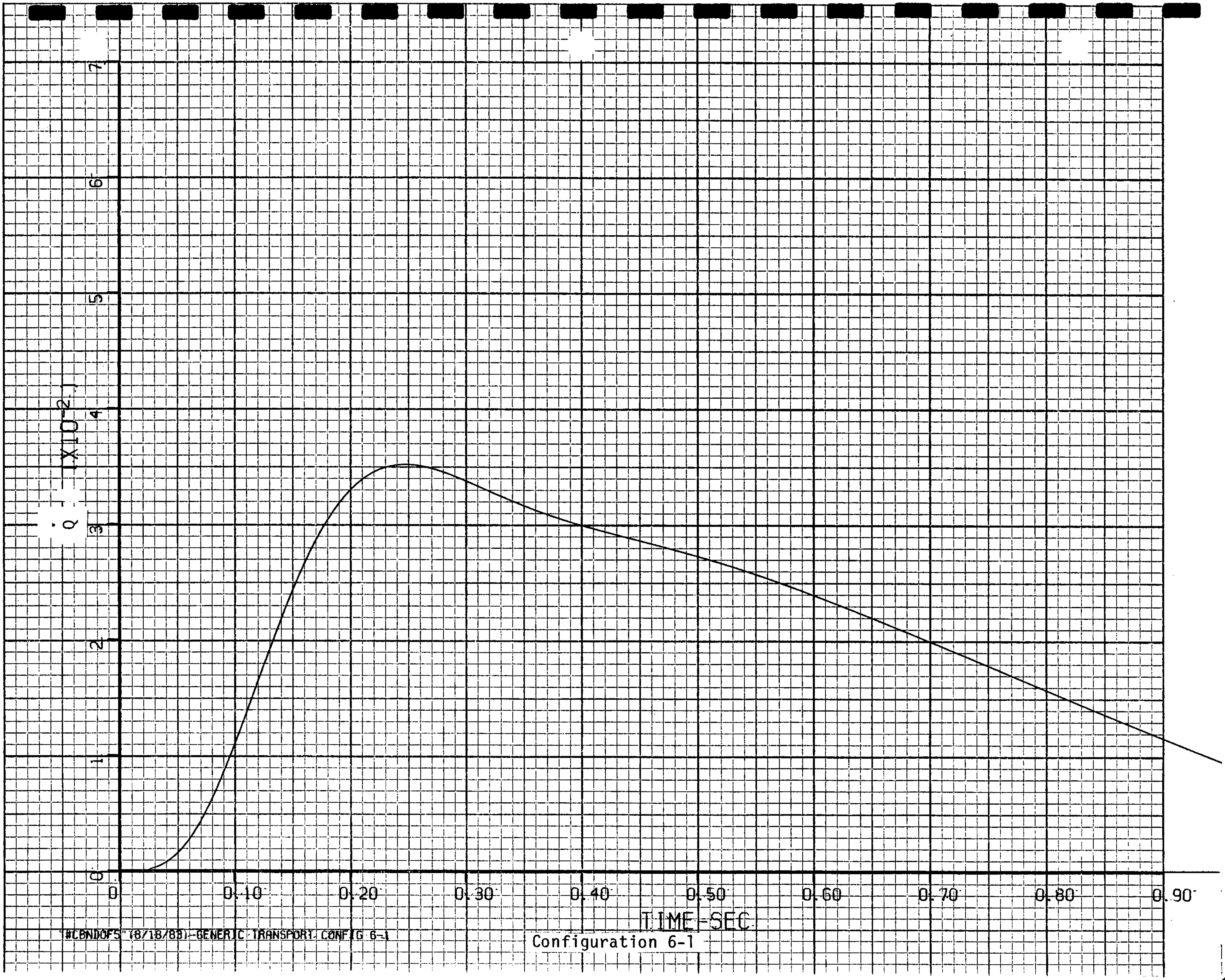
1.0
1.5
2.0
2.5
3.0
3.
Q

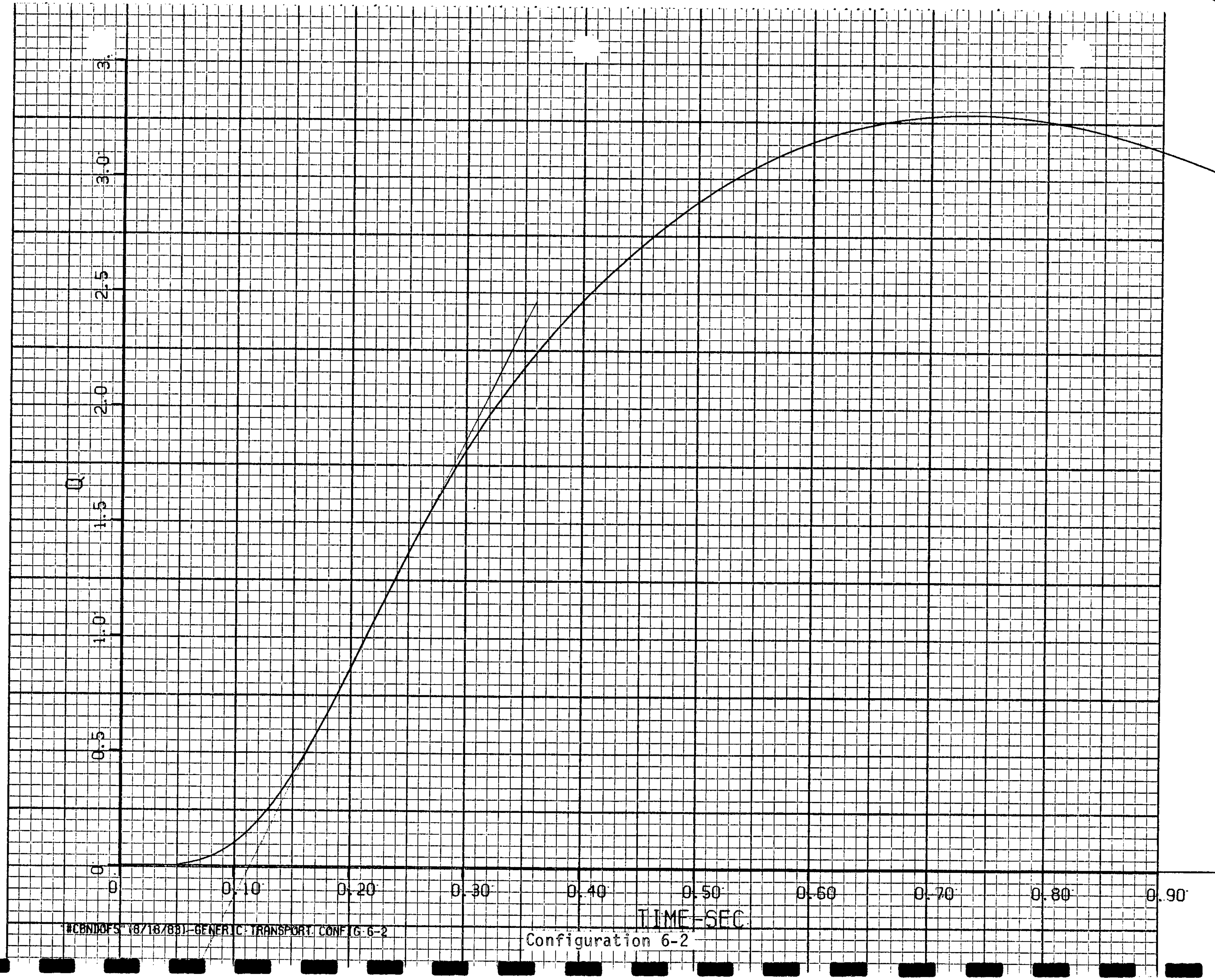


Configuration 5-2

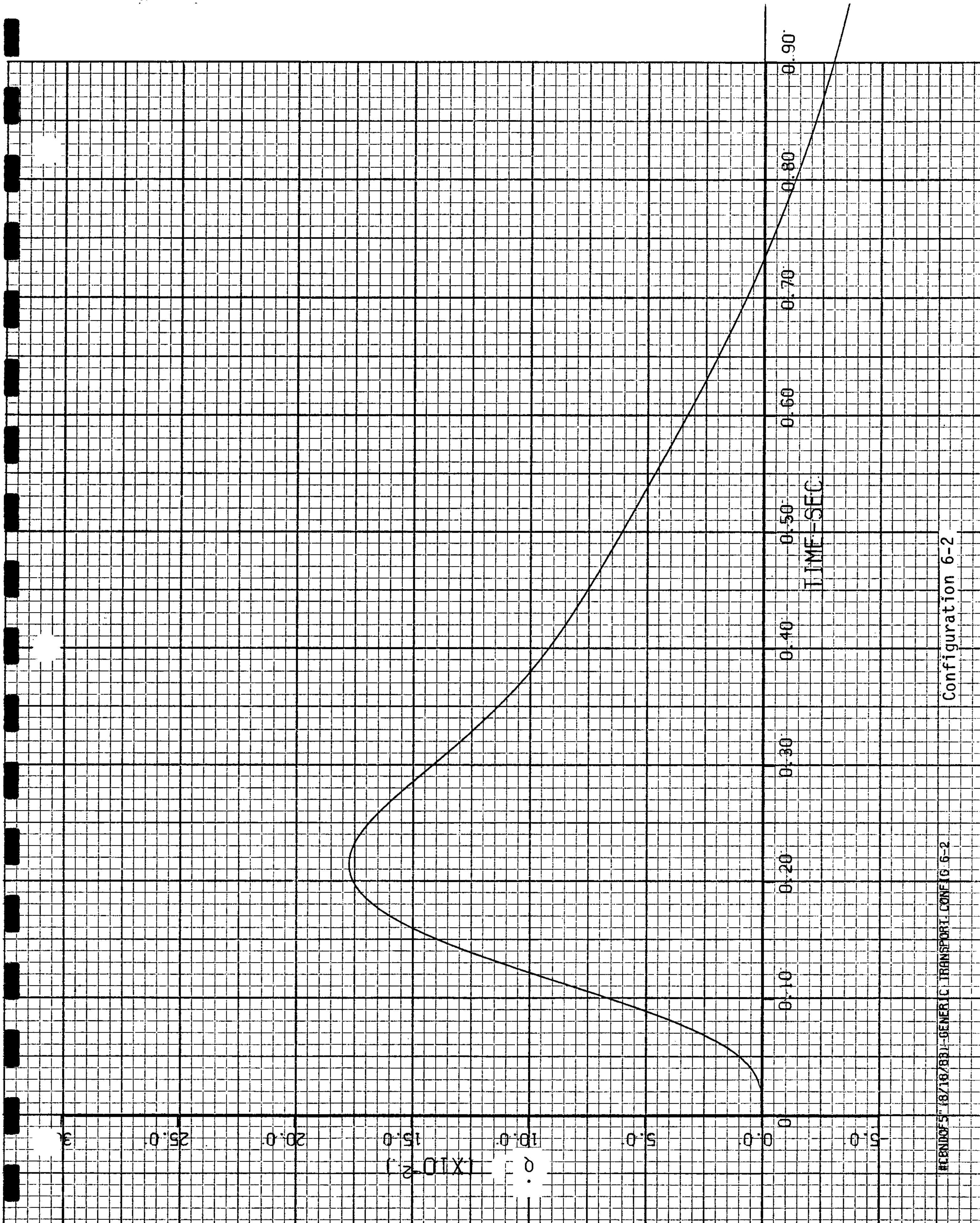

TIME-SEC
Configuration 6-1
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
0.20
0.40
0.60
0.80
1.00
1.20

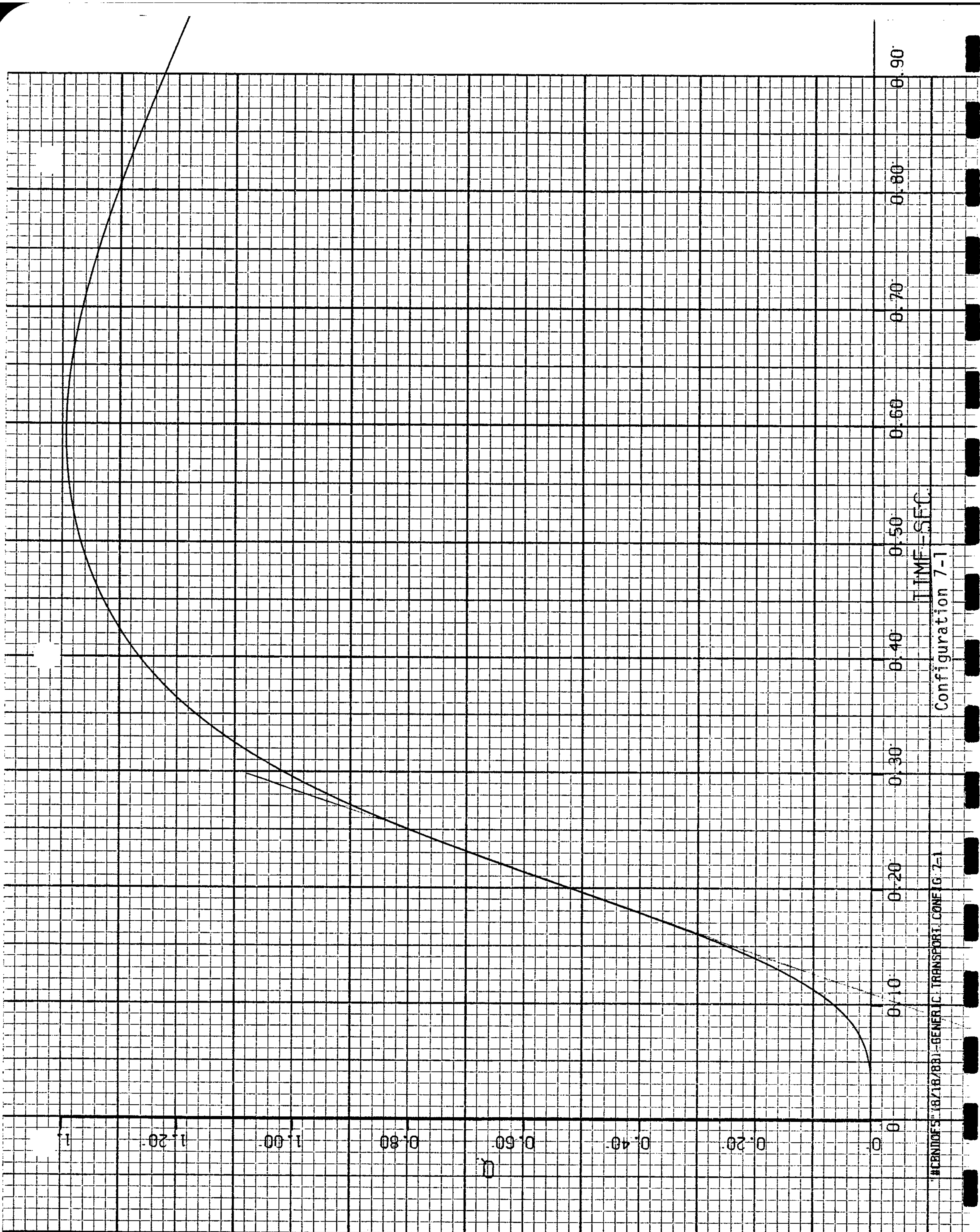


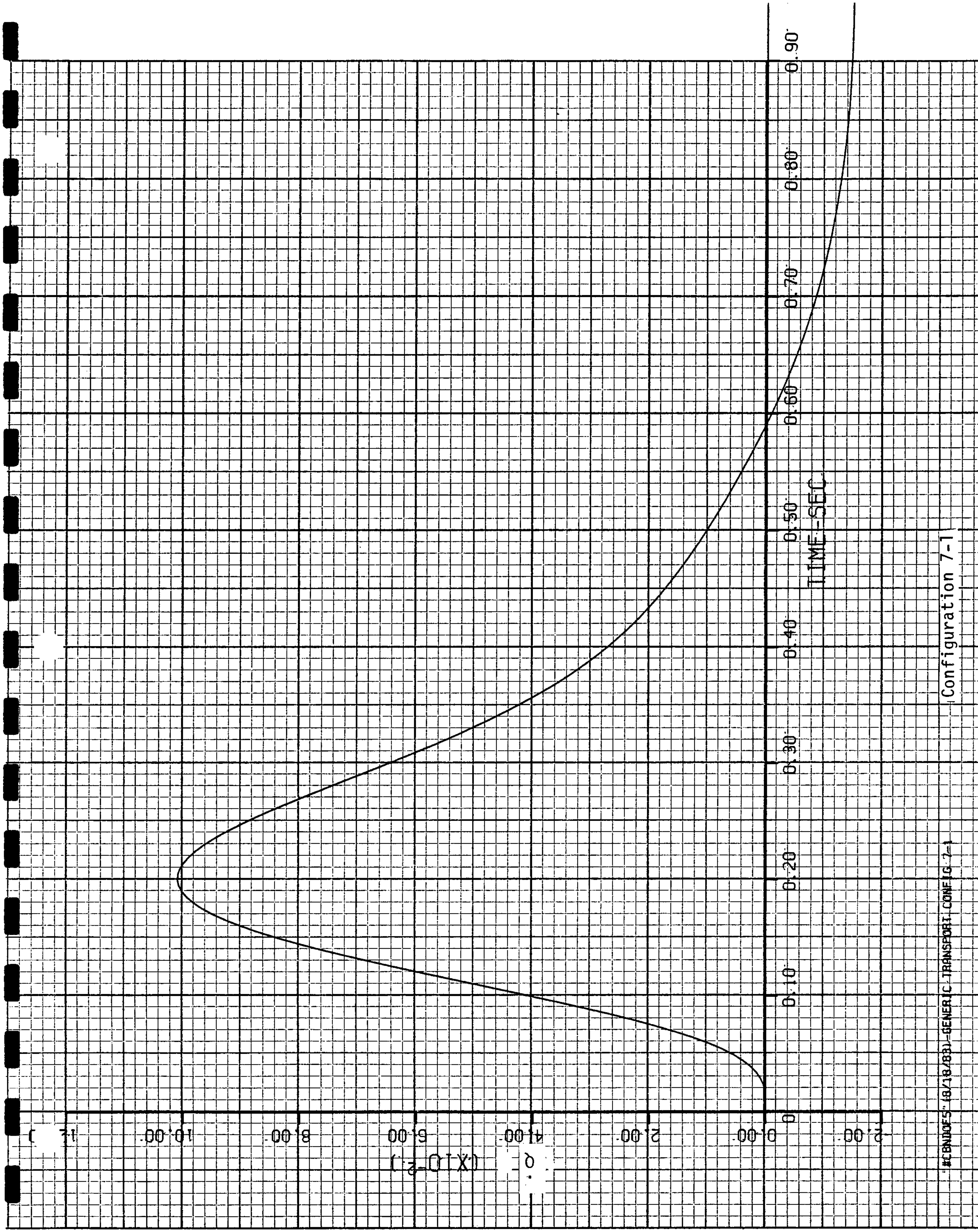
Configuration 6-1

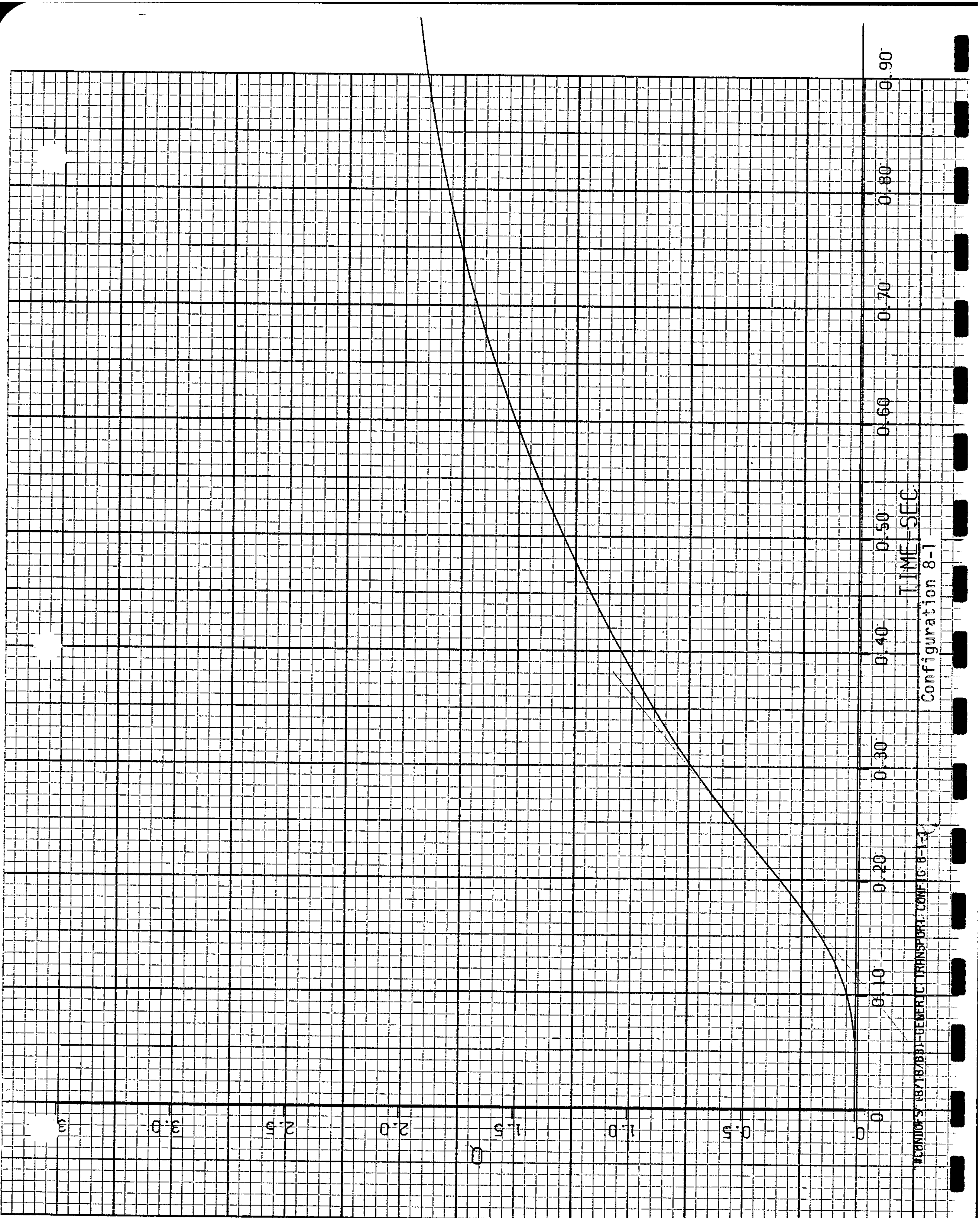


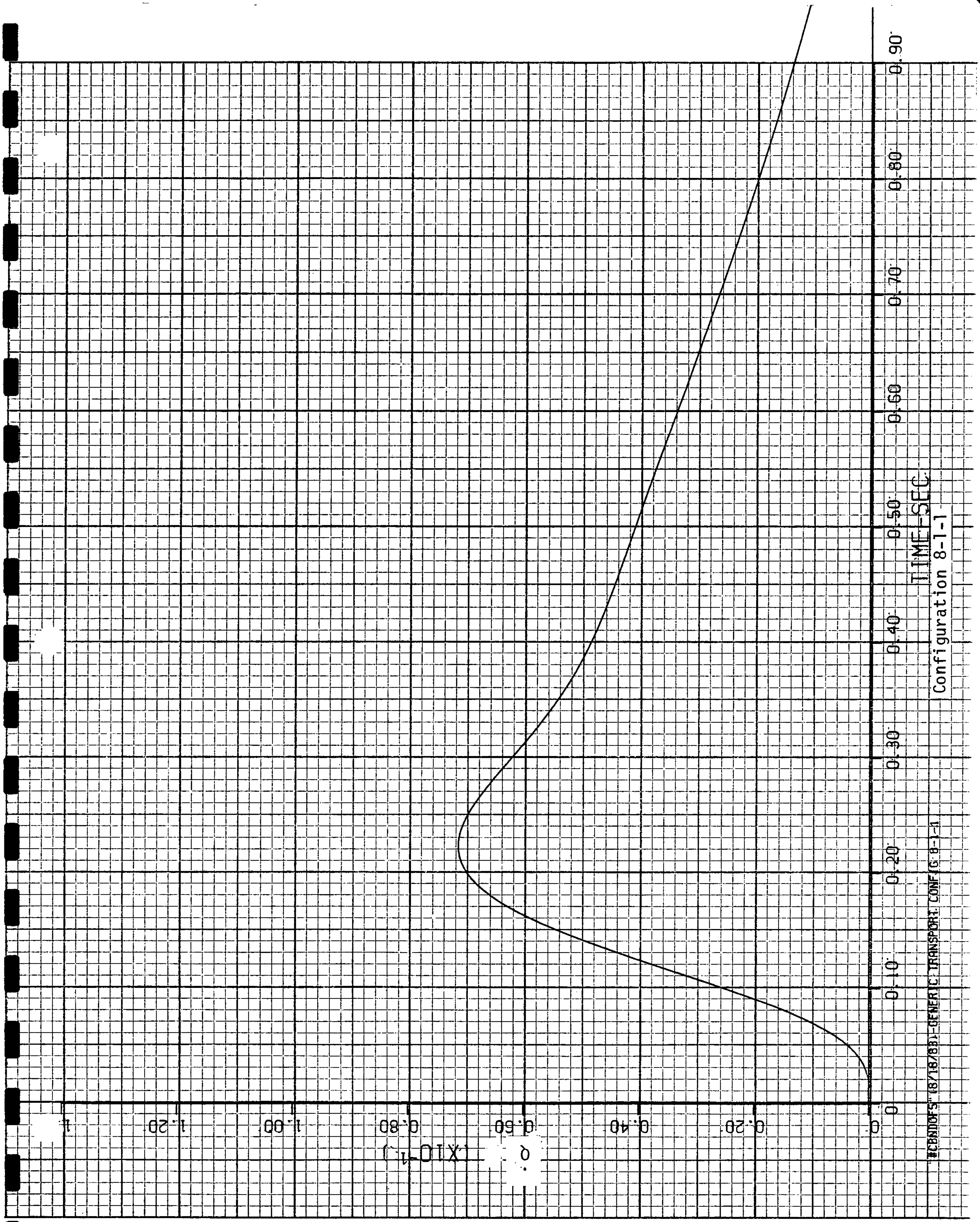
Configuration 6-2


TIME-SEC
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Q (X10-2)
0.0
5.0
10.0
15.0
20.0
25.0
Configuration 6-2
HCBNDOFS (8/18/88)-GENERIC TRANSPORT CONFIG 6-2

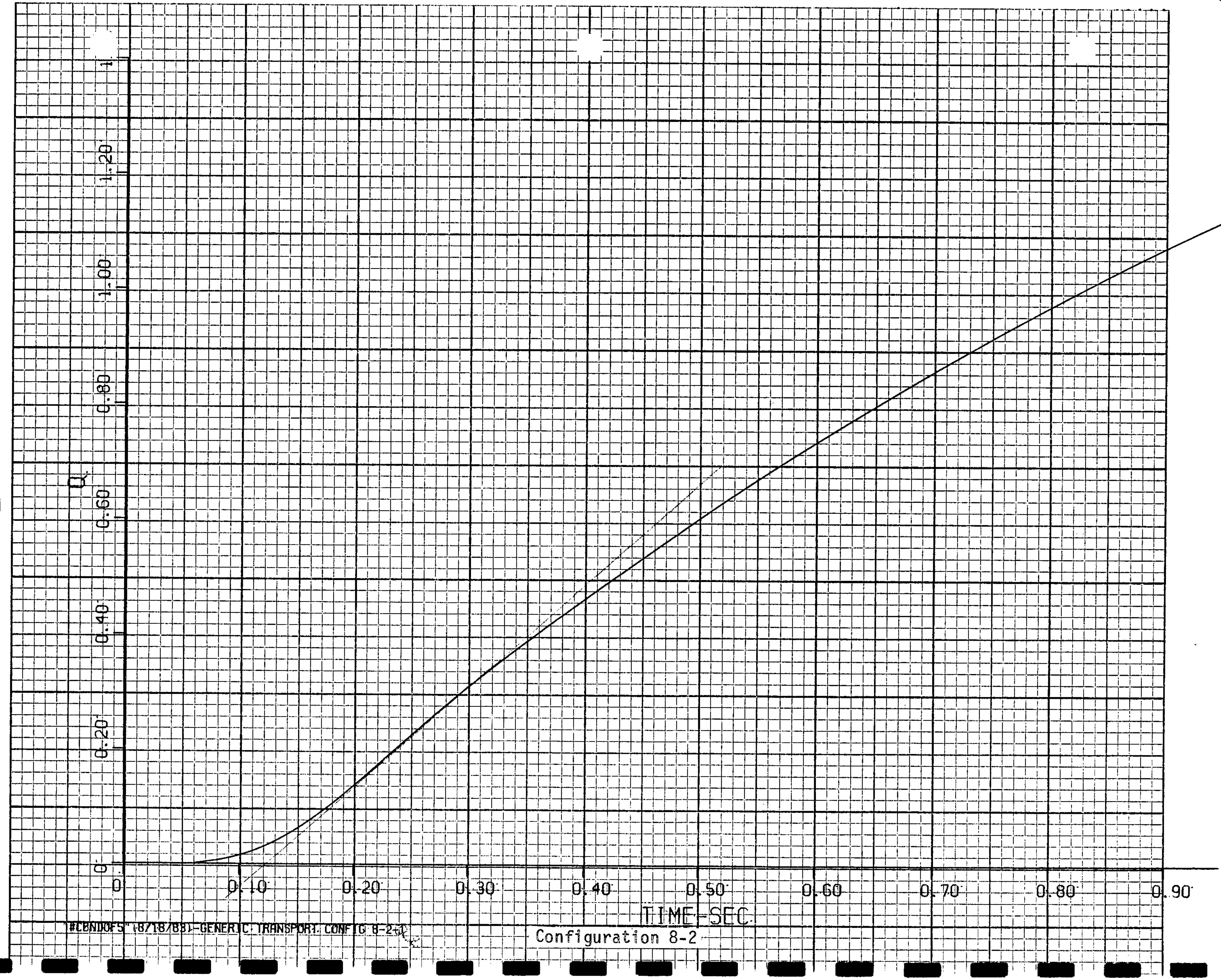

0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
TIME-SEC
Configuration 7-1
#CBNDOFS (8/18/88)-GENERIC TRANSPORT CONFIG 2-1
0.20
0.40
0.60
0.80
1.00
1.20


TIME-SEC
Configuration 7-1
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
10.00
8.00
6.00
4.00
2.00
0.00
-2.00

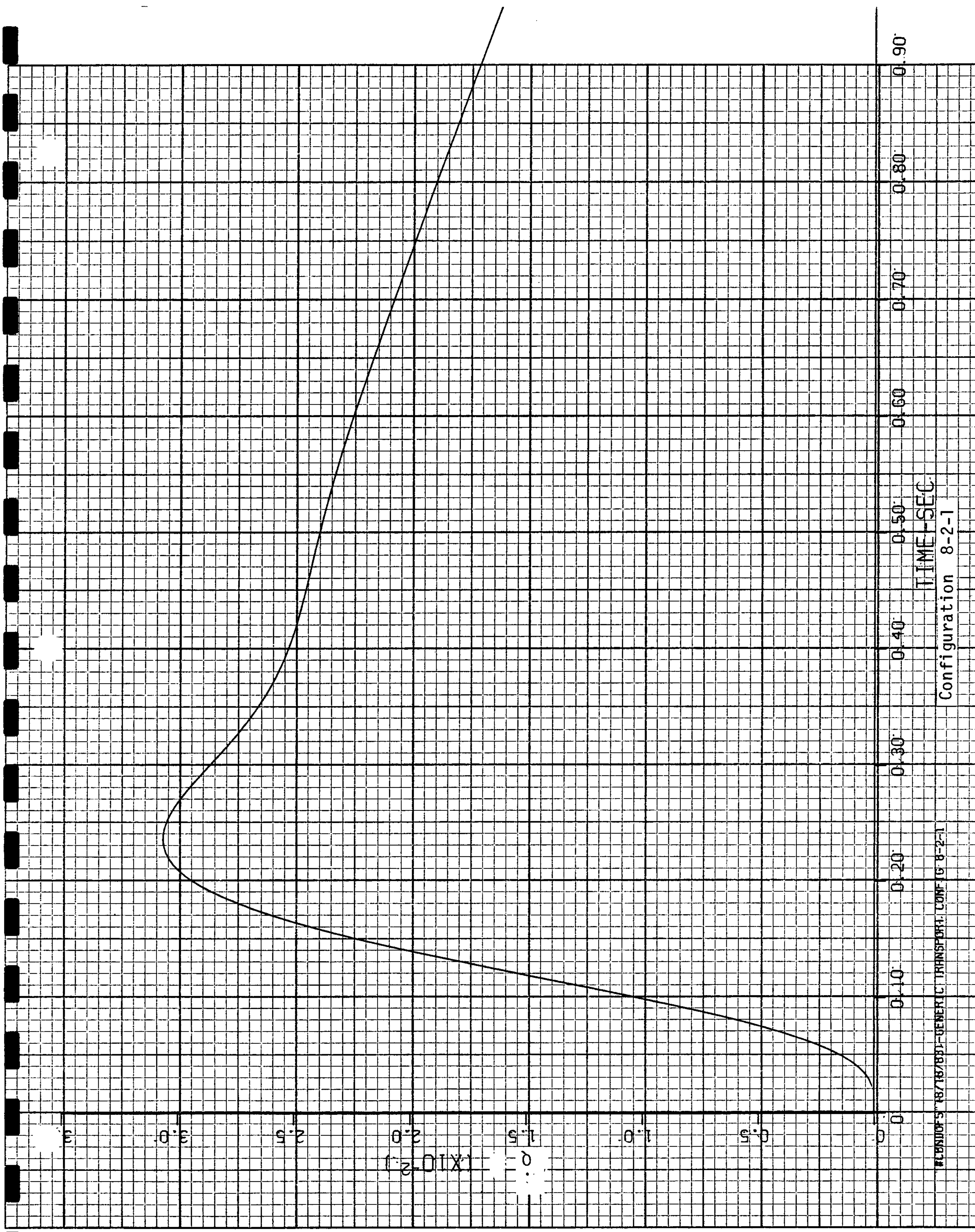

TIME-SEC
Configuration 8-1
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Q
0
0.5
1.0
1.5
2.0
2.5
3.0
GENERIC TRANSPORT CONFIG



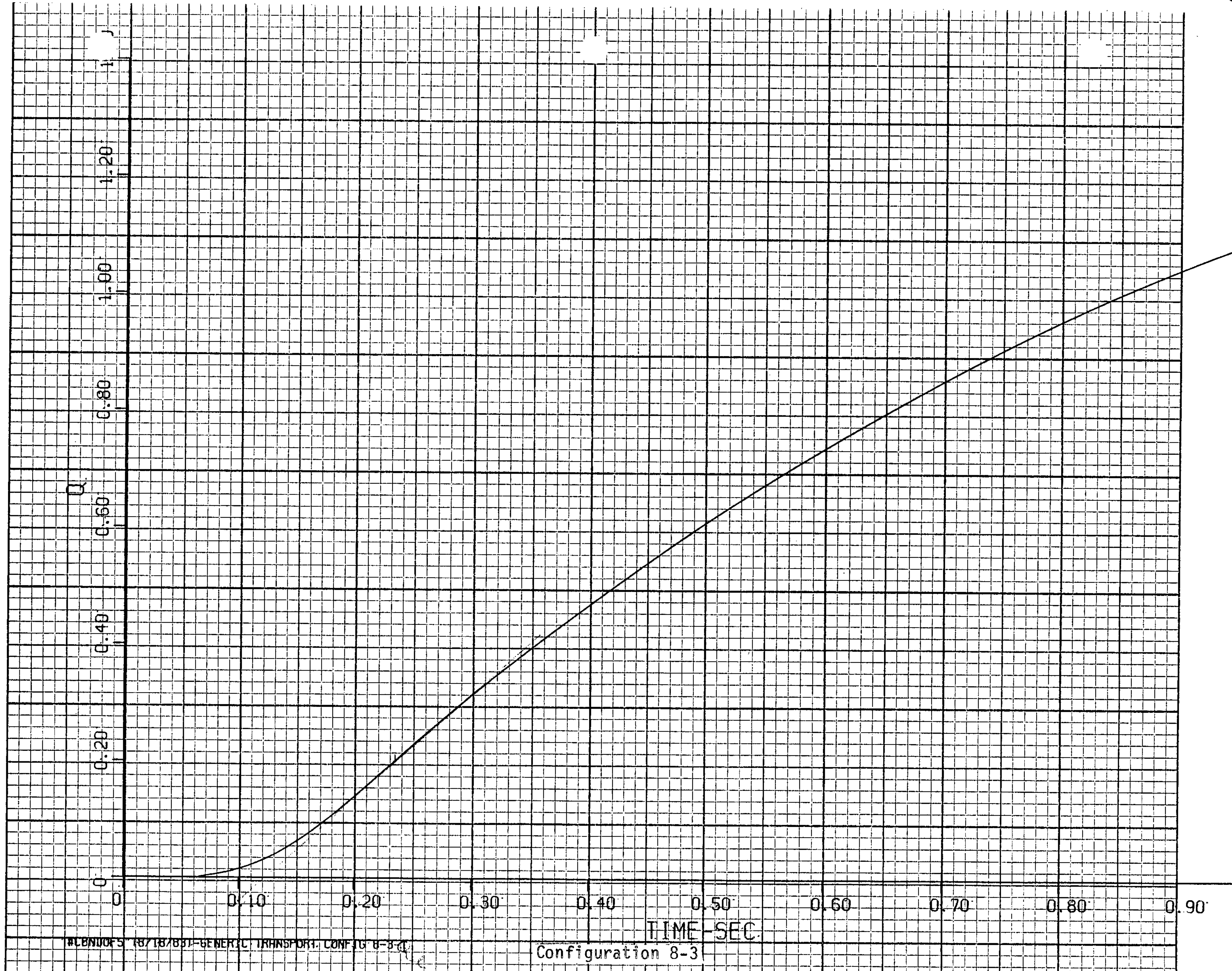
Configuration 8-1-1
TIME-SEC
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Q (X10-1)
0
0.20
0.40
0.60
0.80
1.00
1.20
#CBNDOFS (8/18/83)-GENERIC TRANSPORT CONFIG 8-1-1



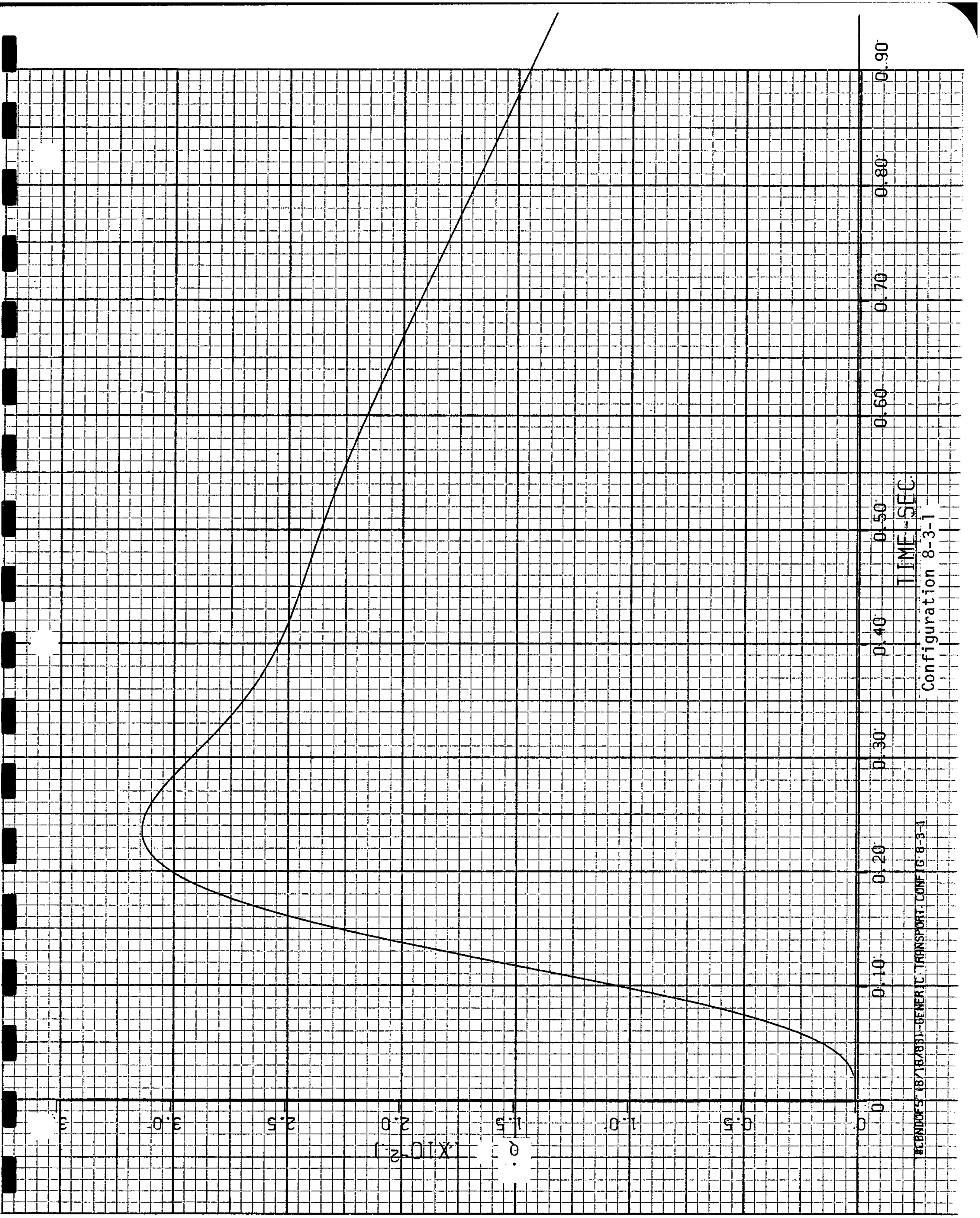
Configuration 8-2



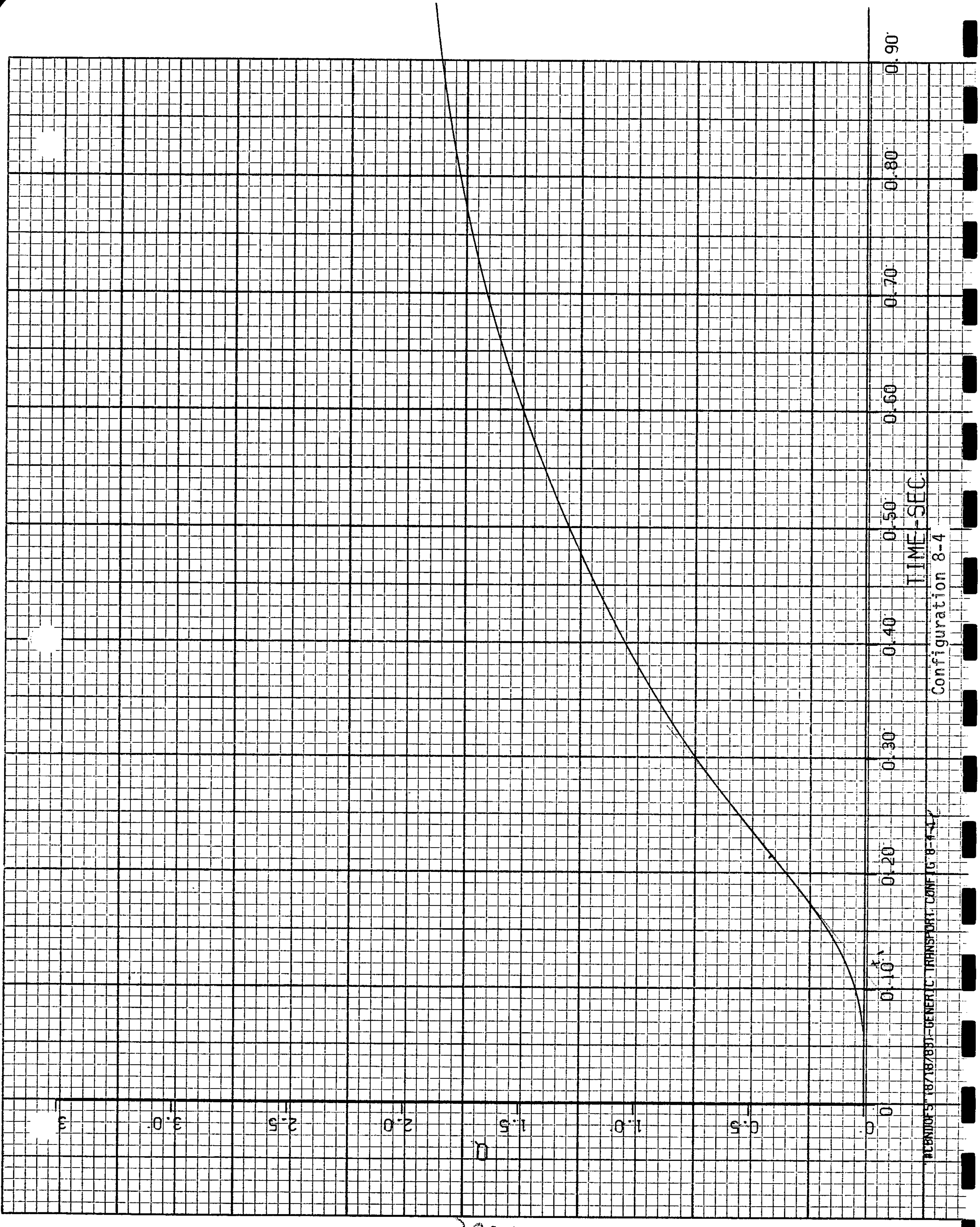
Configuration 8-2-1



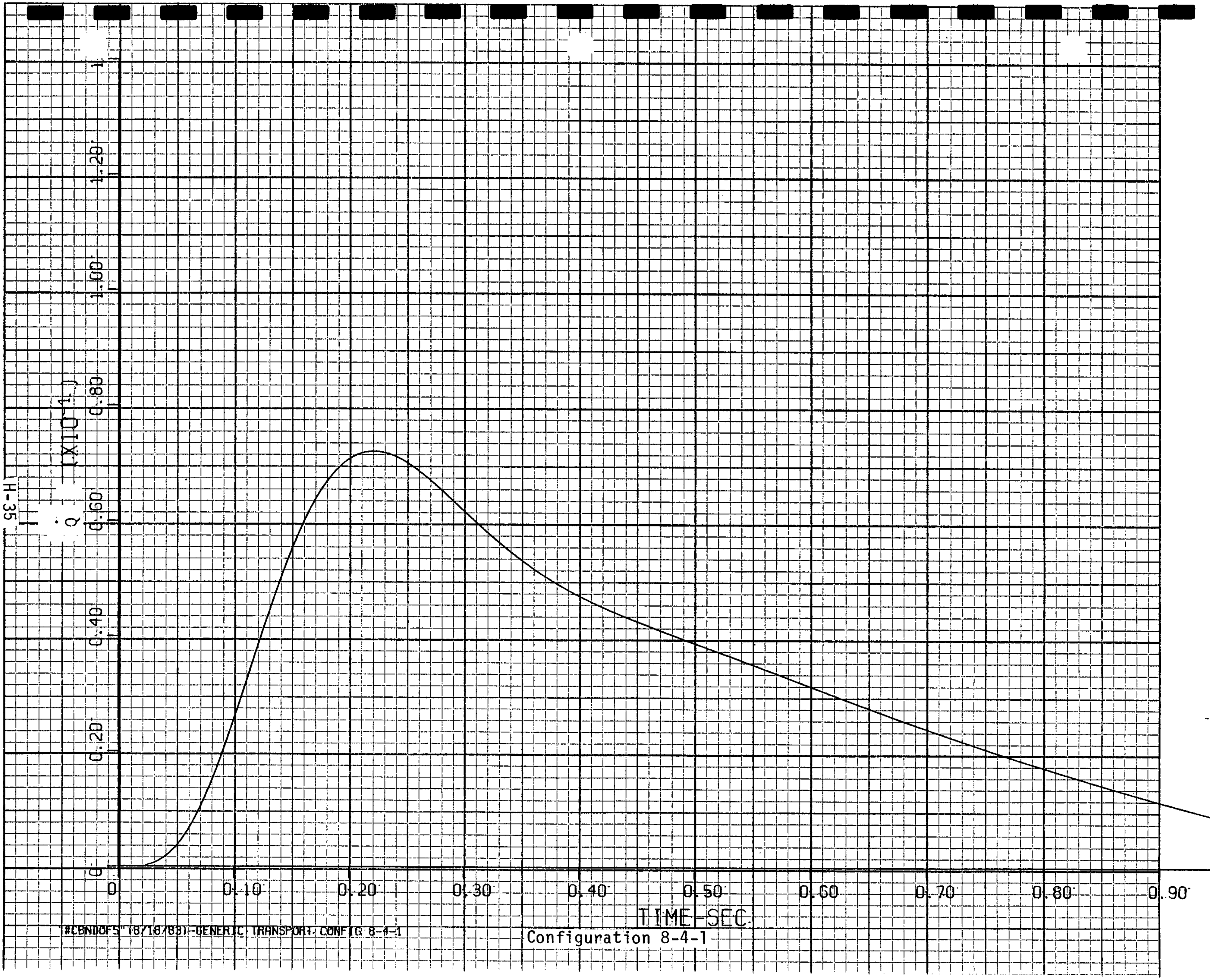
Configuration 8-3



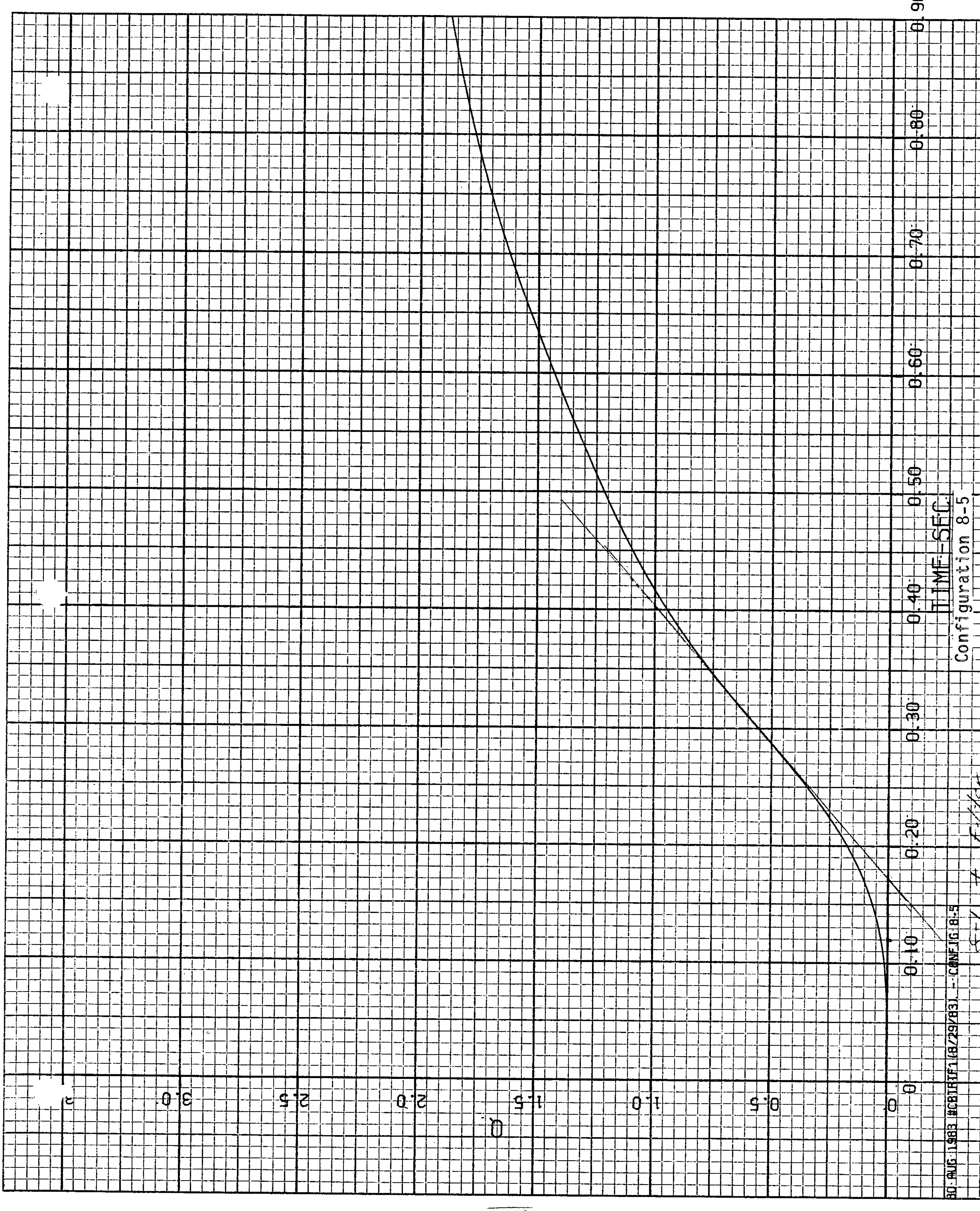
Configuration 8-3-1


TIME-SEC
Configuration 8-4
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
0
0.5
1.0
1.5
2.0
2.5
3.0

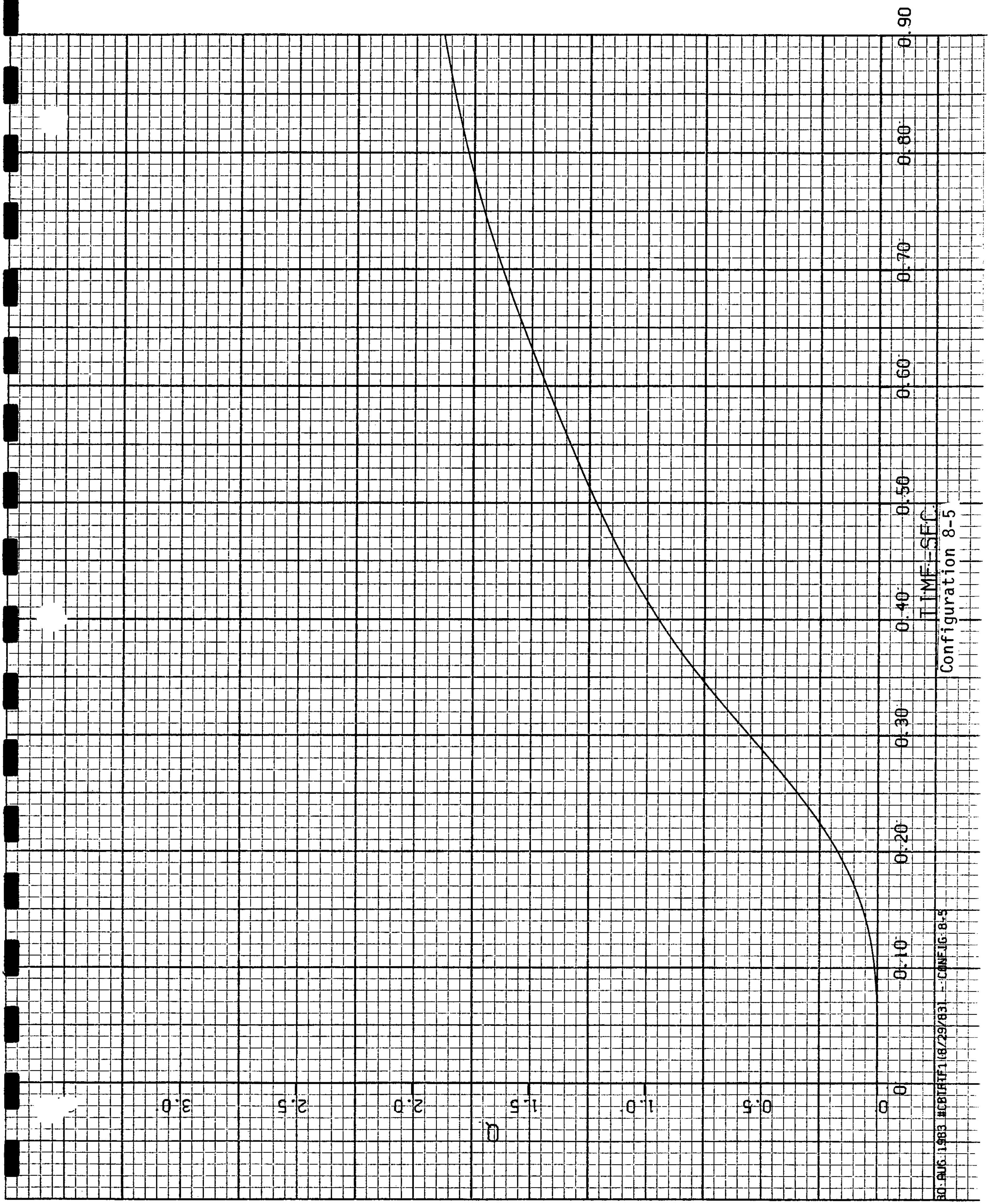
$\dot{q}$ rad/sec^2

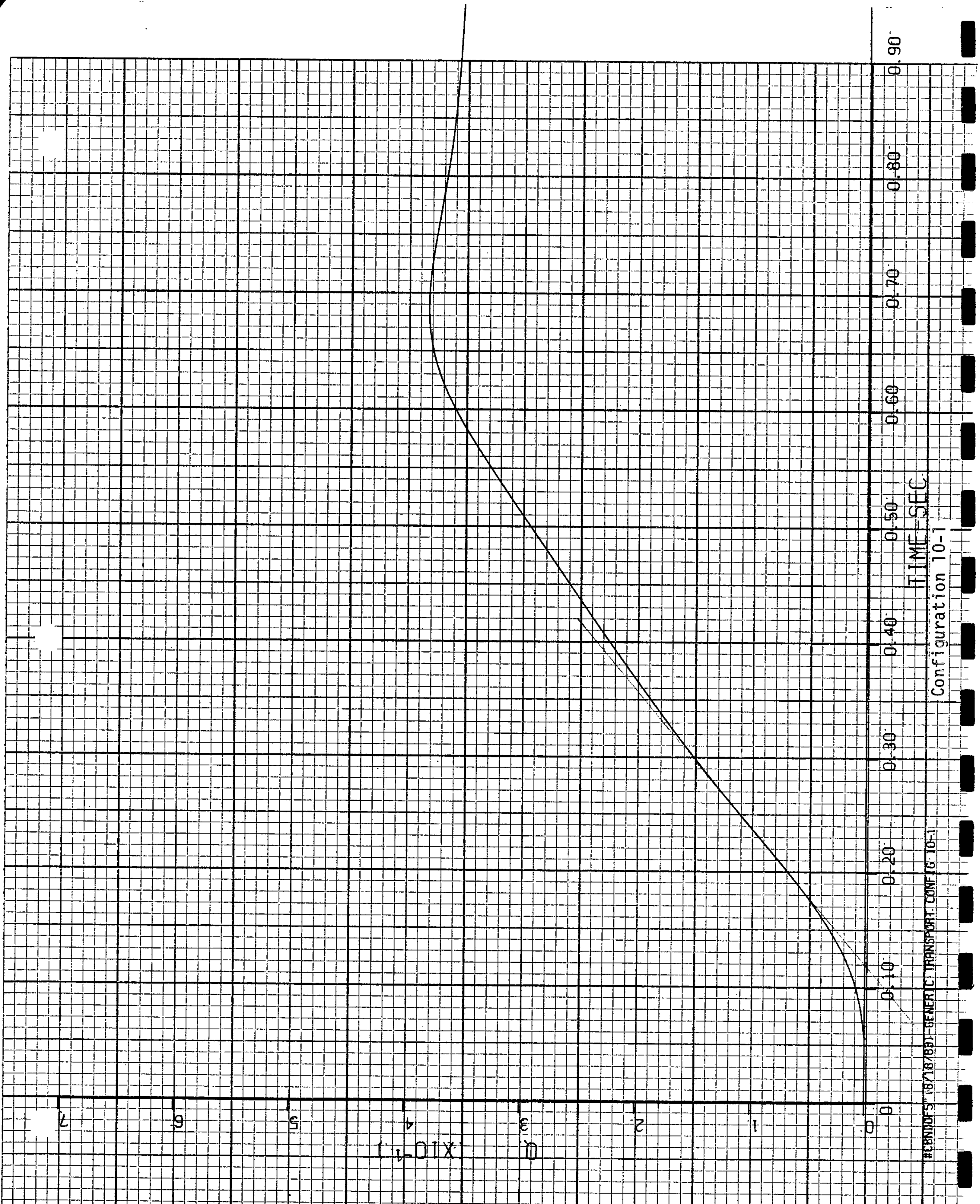


Configuration 8-4-1

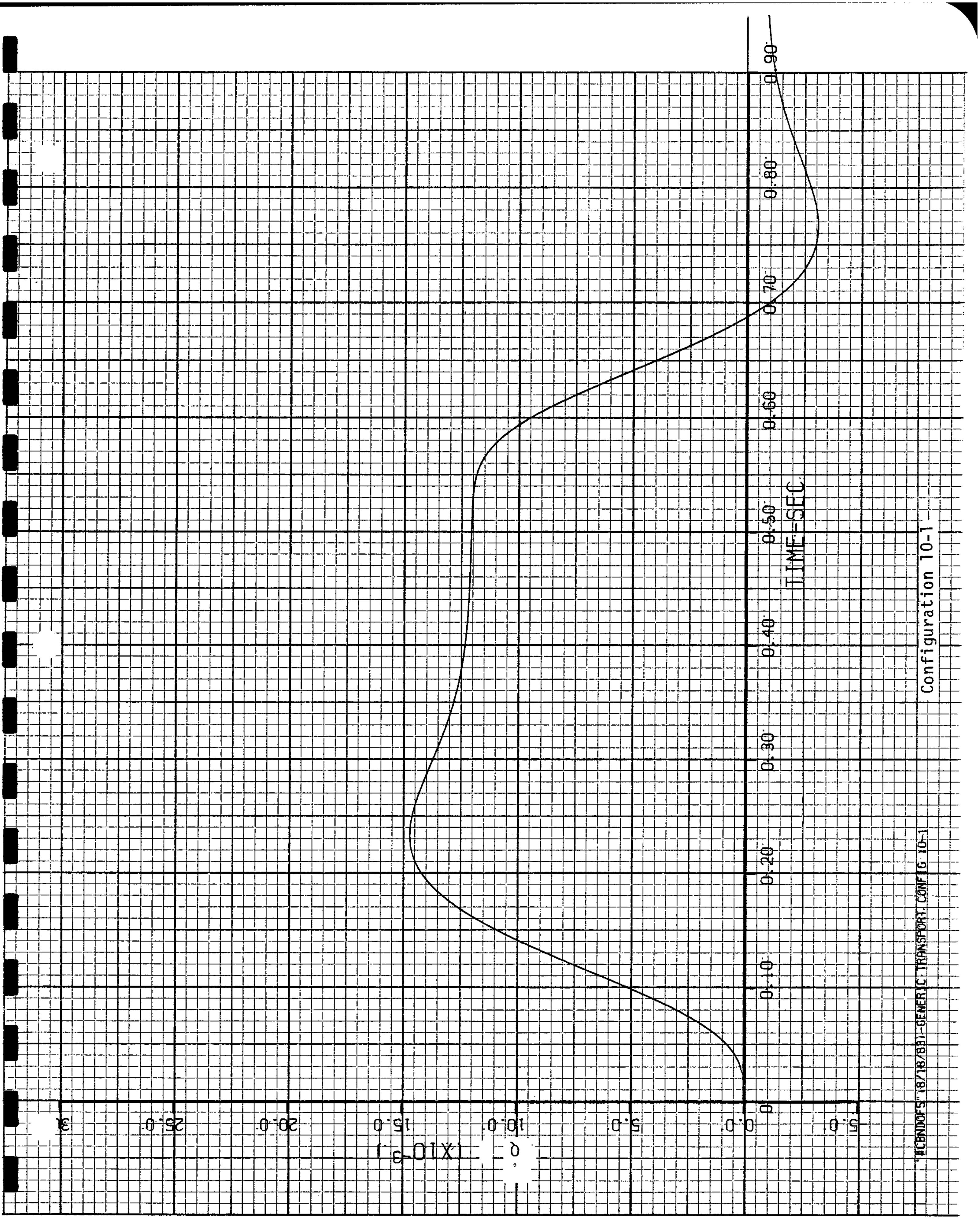


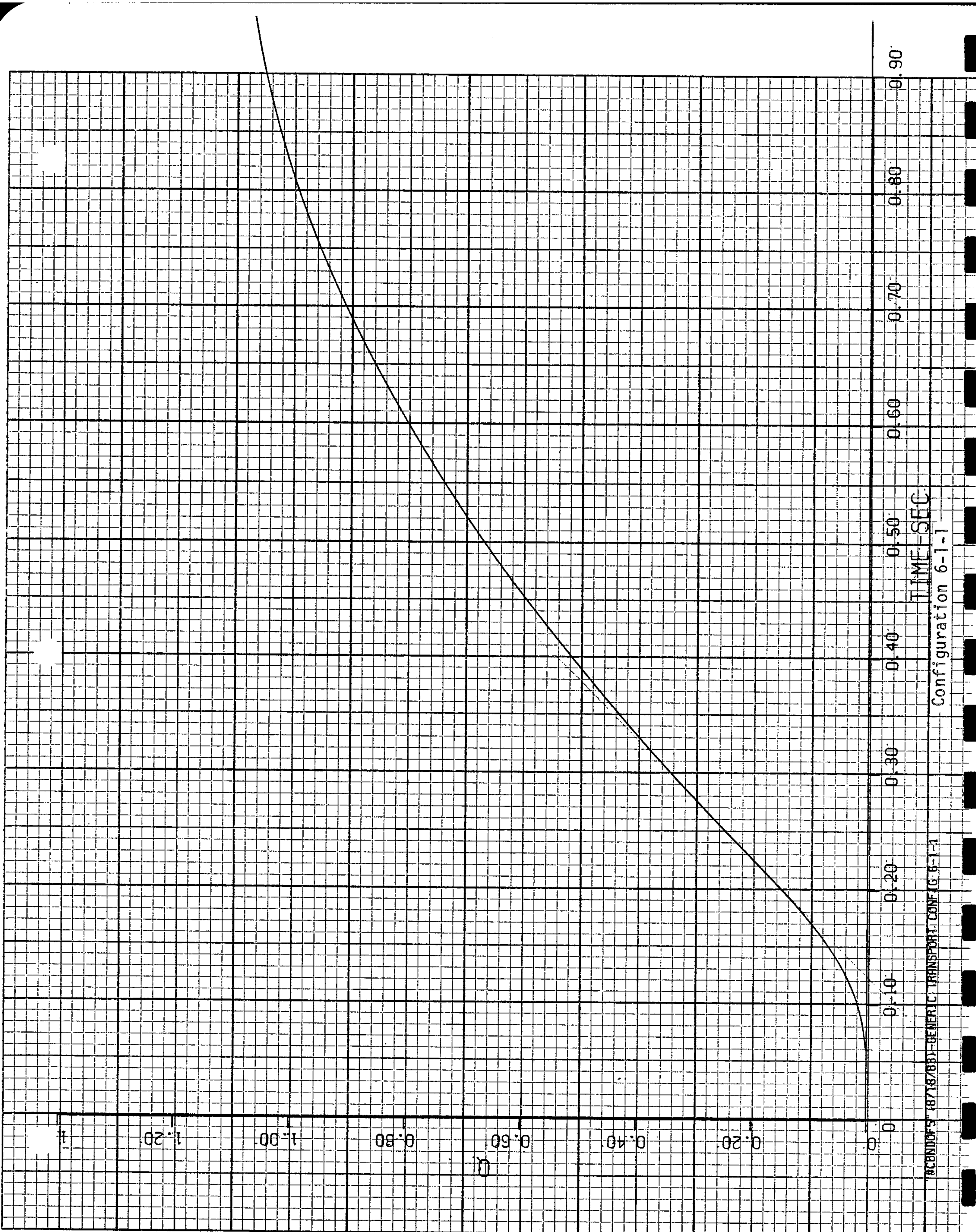
Configuration 8-5

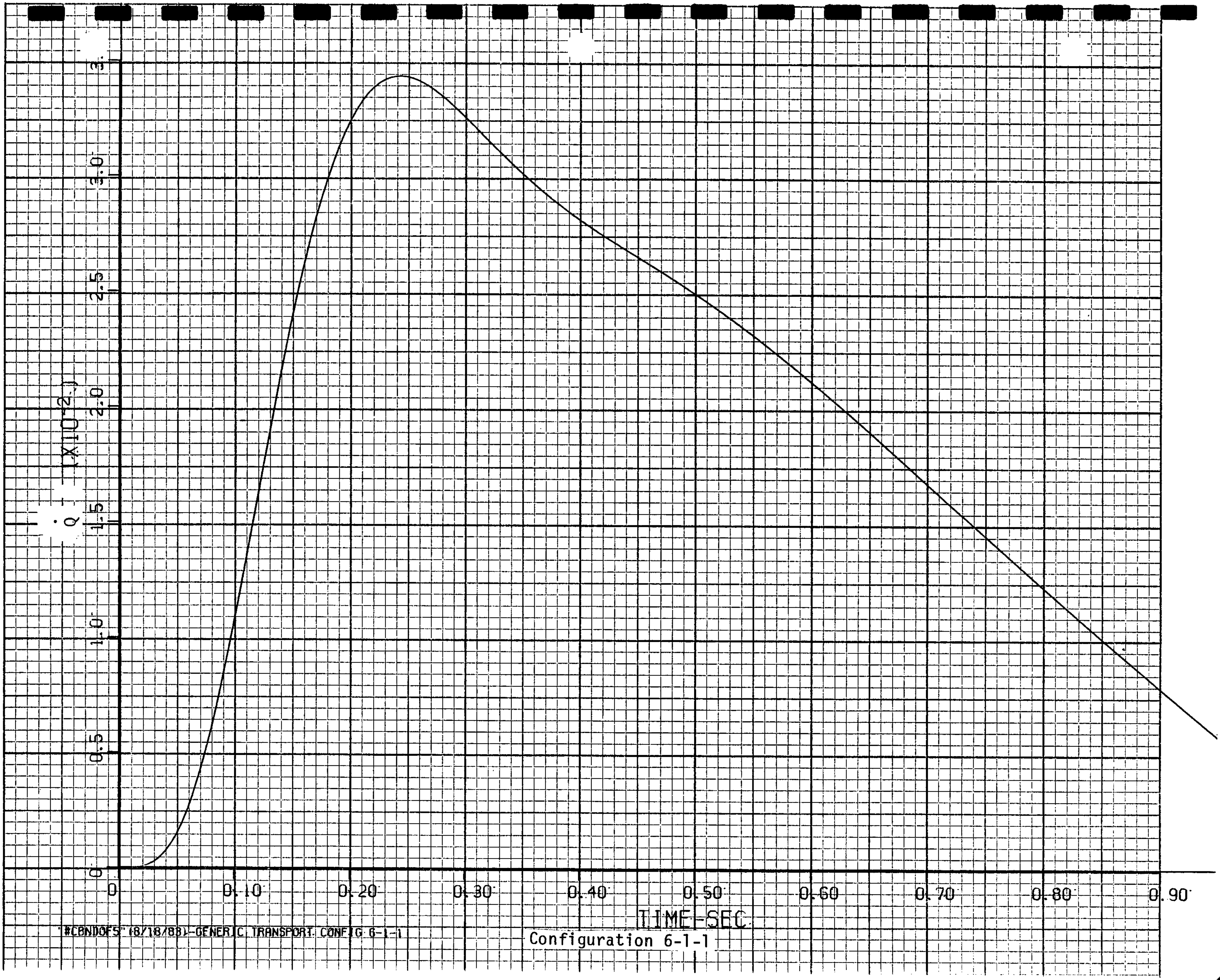

0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
TIME - SEC.
Configuration 8-5
0
0.5
1.0
1.5
2.0
2.5
3.0
Q
30 AUG 1983 #CBTRIF1(8/29/83) - CONFIG 8-5



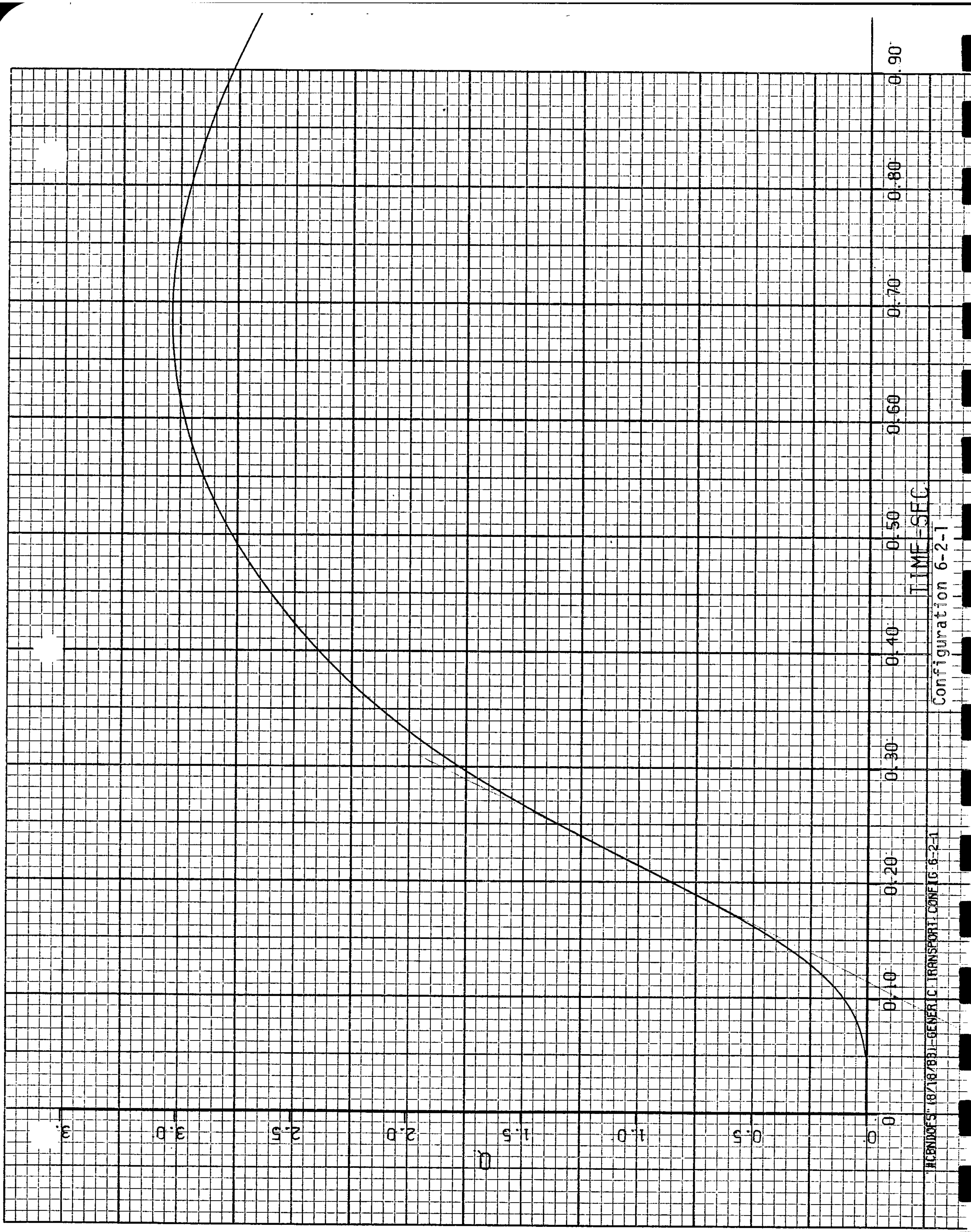
TIME-SEC
Configuration 10-1
#CBNDOFS (8/18/88)-GENERIC TRANSPORT CONFIG 10-1
Q (X10^{-1})
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1
2
3
4
5
6
7


"HCBNDOFS" (8/18/88)-GENERIC TRANSPORT CONFIG 10-1
Configuration 10-1
TIME-SEC
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
-5.0
0.0
5.0
10.0
15.0
20.0
25.0
3
(X10^-3)

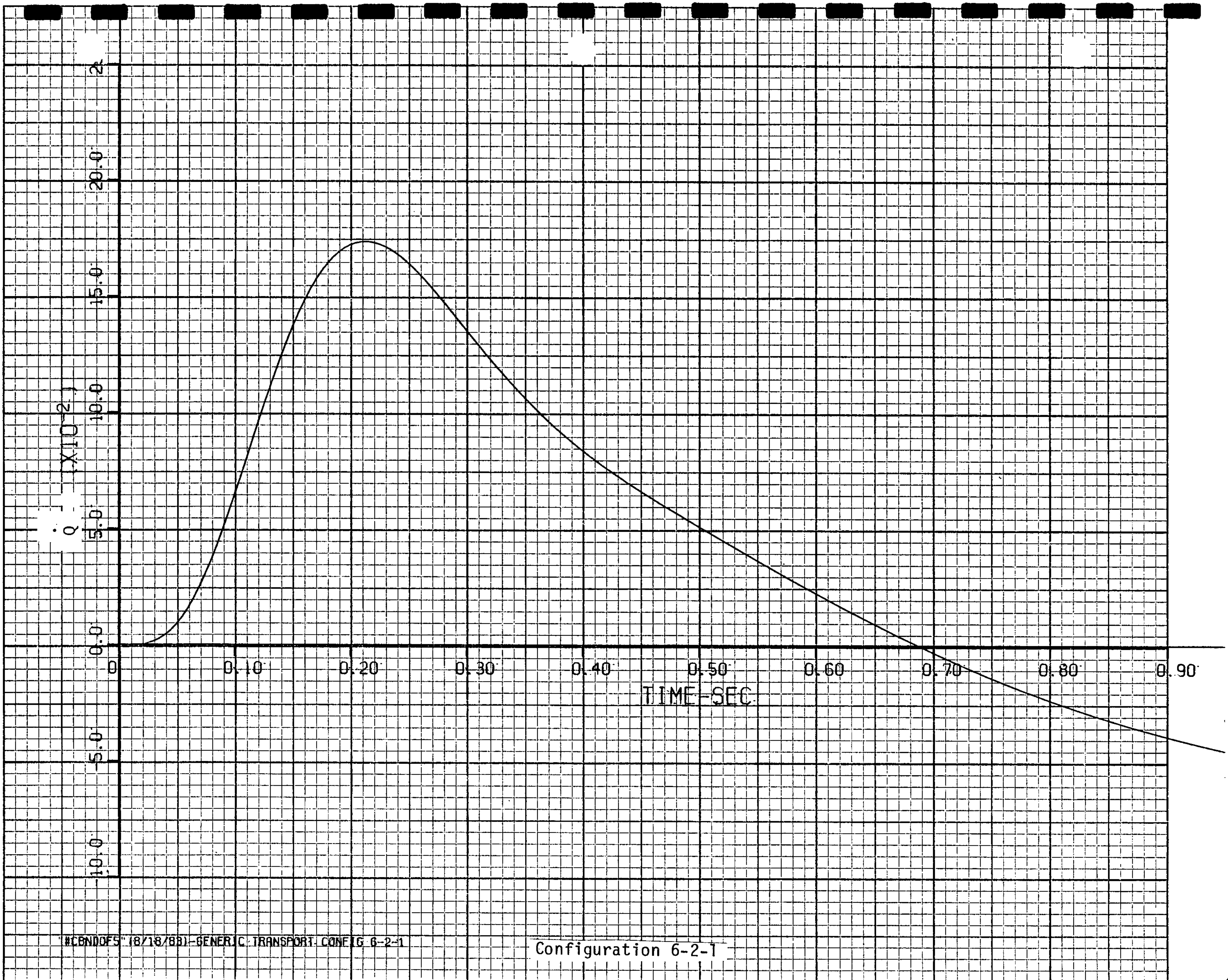

TIME-SEC
Configuration 6-1-1
WCBNDOFS (8/18/88)-GENERIC TRANSPORT CONFIG 6-1-1
0
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Q
0
0.20
0.40
0.60
0.80
1.00
1.20



Configuration 6-1-1



Configuration 6-2-1



Configuration 6-2-1

APPENDIX I

ROOT LOCUS PLOTS

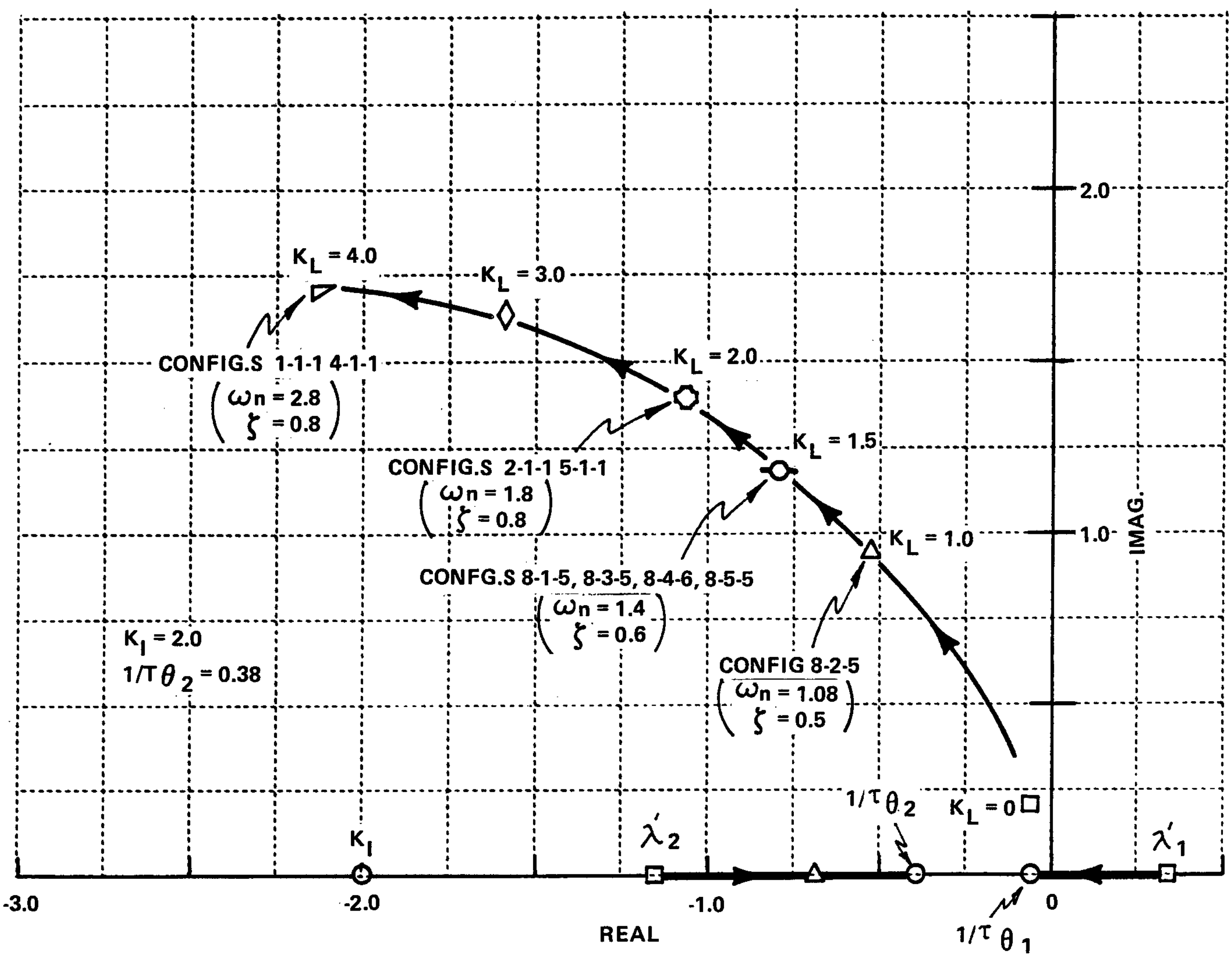


Figure I-1 ROOT LOCUS (CONFIGS, 1-1-1, 4-1-1, 2-1-1, 5-1-1, 8-1-5, 8-2-5, 8-3-5, 8-4-6, 8-5-5)
(FOR PRE FILTER ROOTS SEE TEXT)

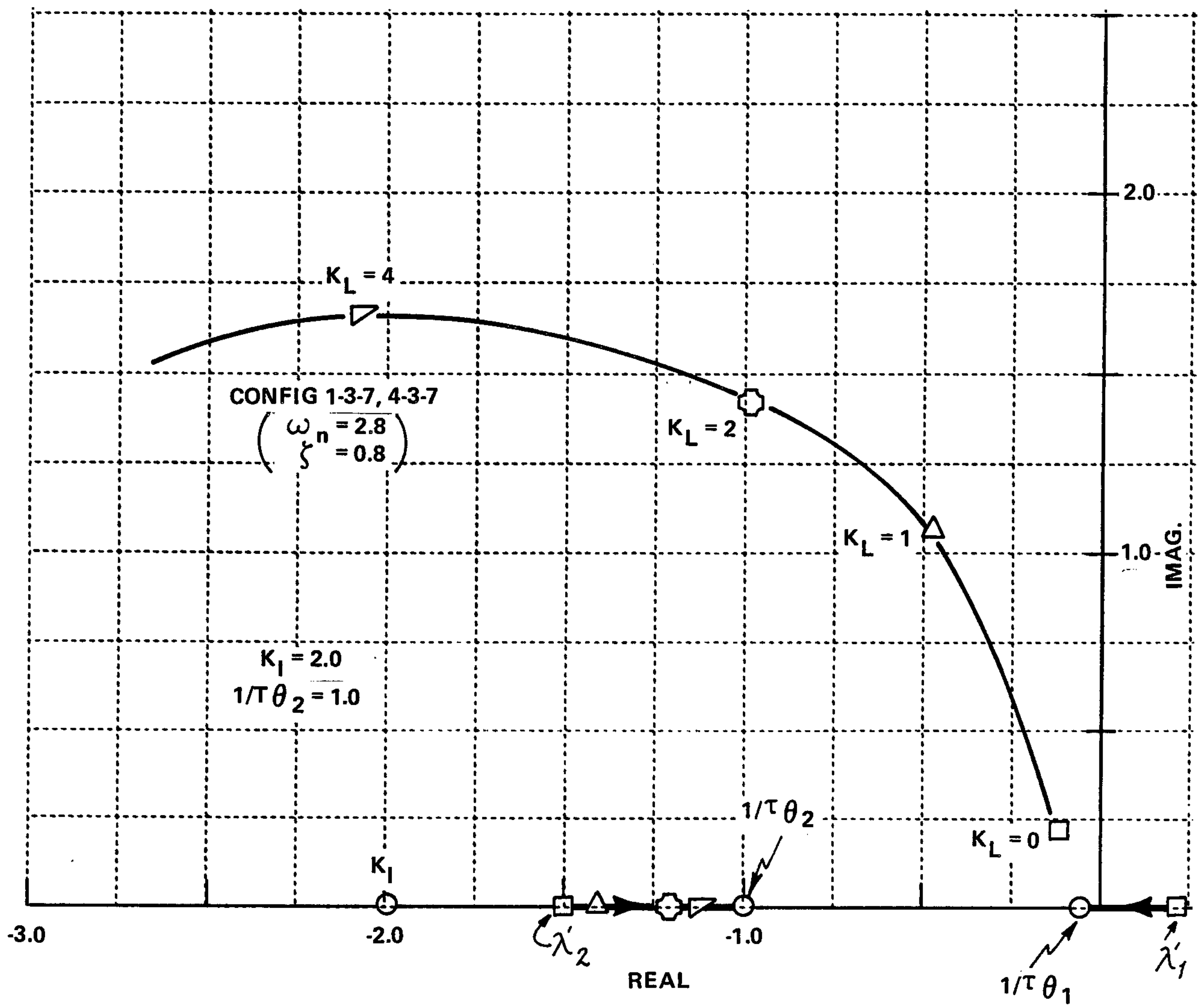


Figure I-2 ROOT LOCUS (CONFIG.S 1-3-7, 4-3-7)

(FOR PRE FILTER ROOTS SEE TEXT)

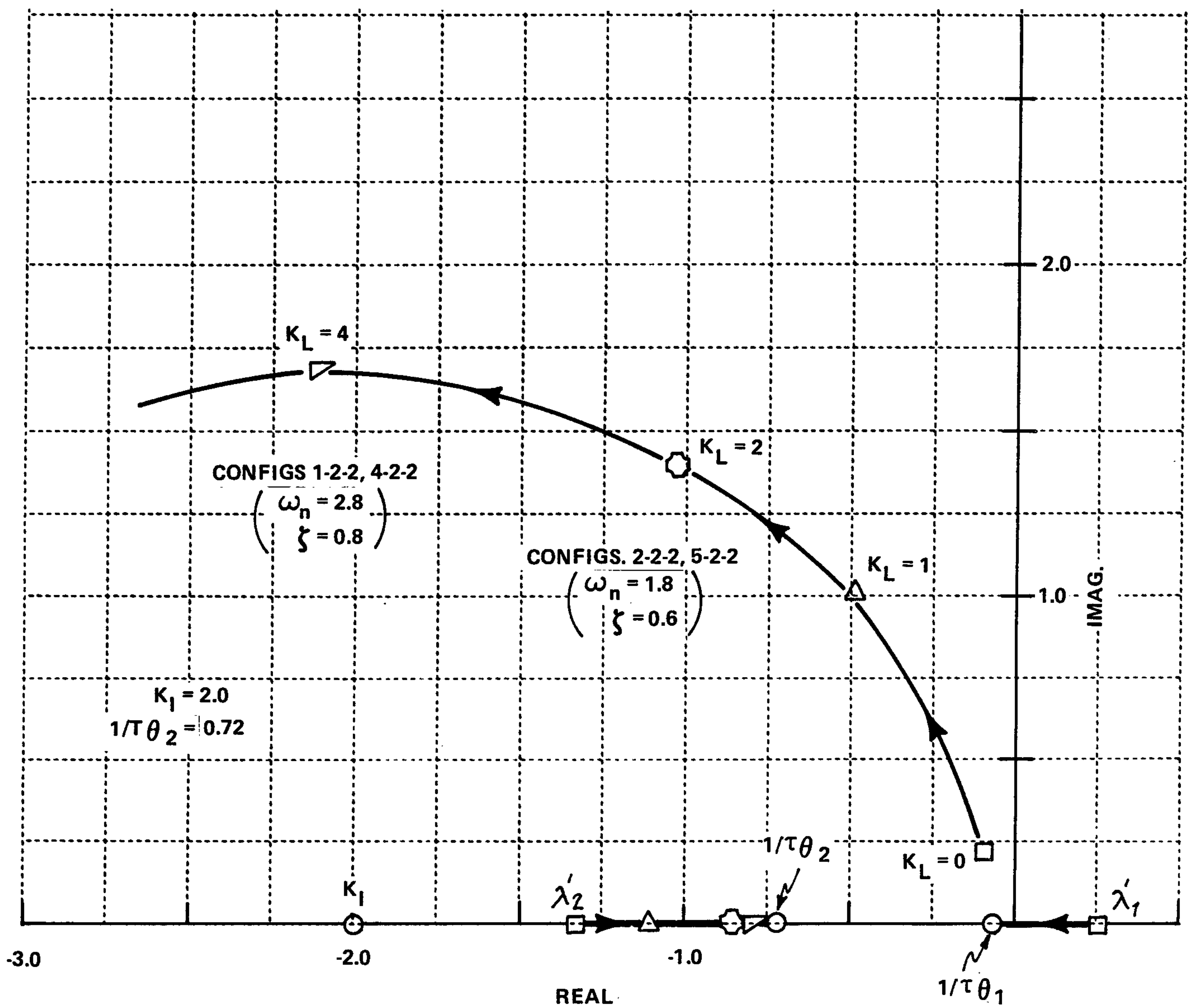


Figure I-3 ROOT LOCUS (CONFIG. 8 1-2-2, 4-2-2, 2-2-2, 5-2-2)

(FOR PRE FILTER ROOTS SEE TEXT)

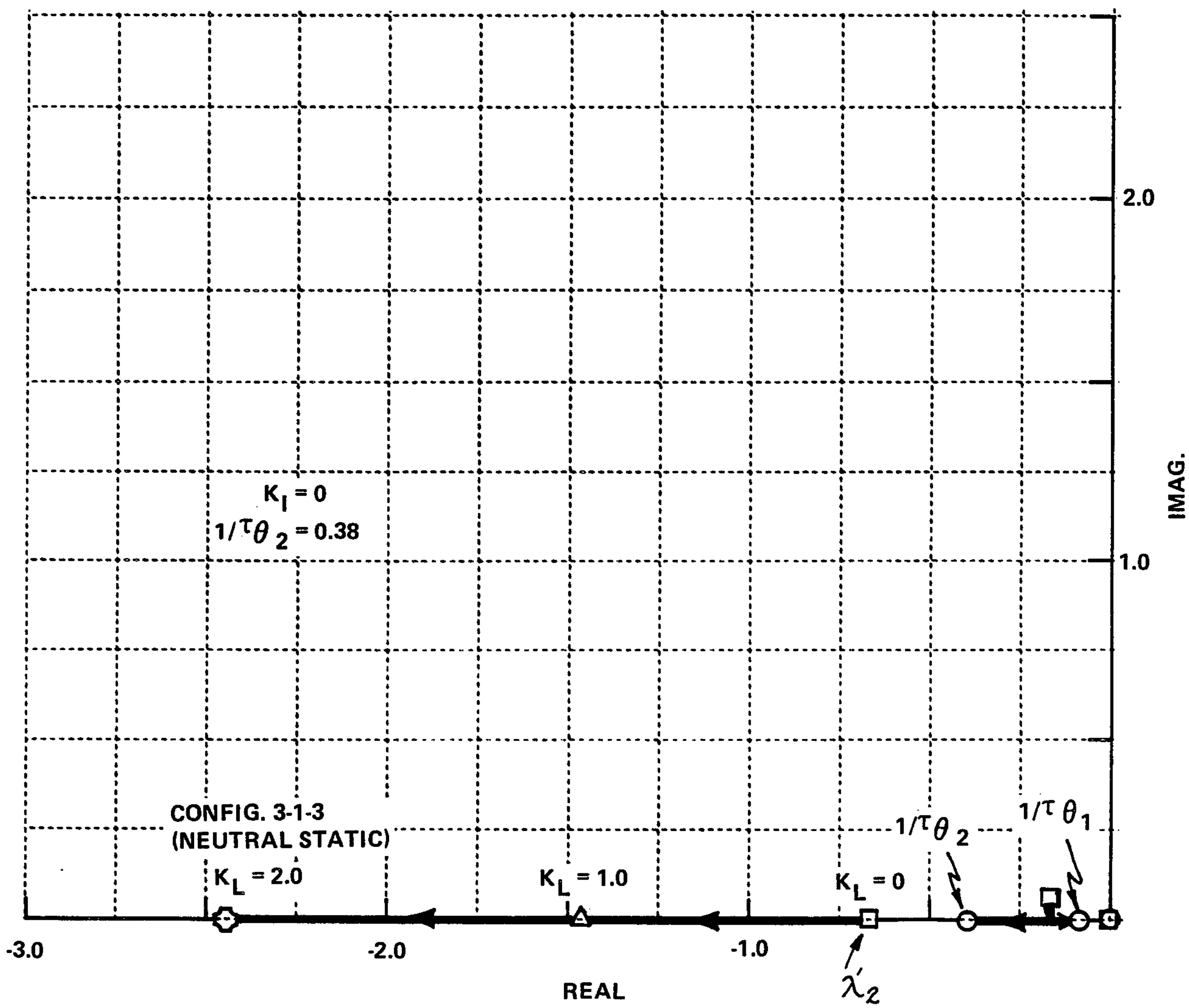


Figure I-4 ROOT LOCUS (CONFIG. 3-1-3)

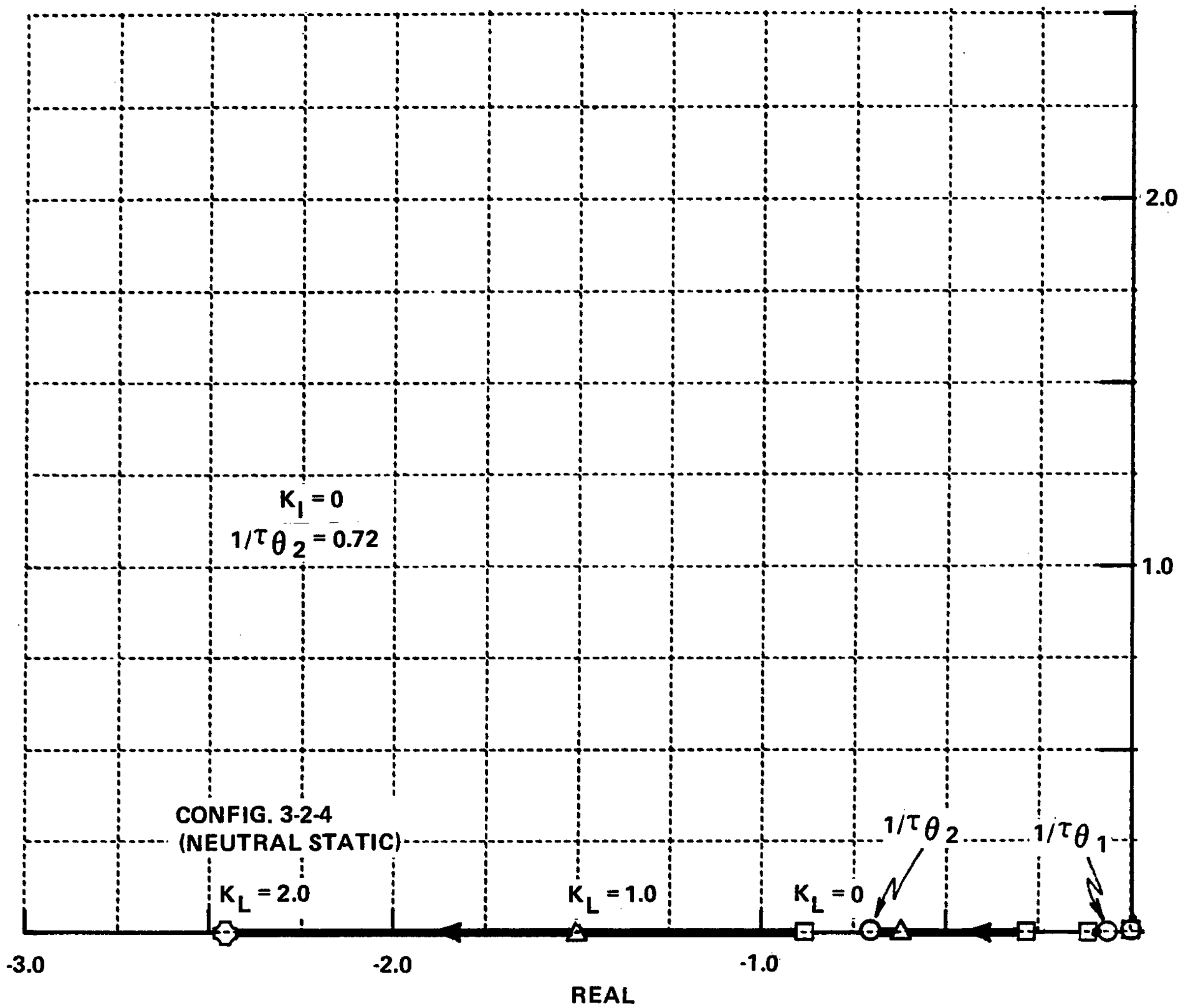


Figure I-5 ROOT LOCUS (CONFIG. 3-2-3)

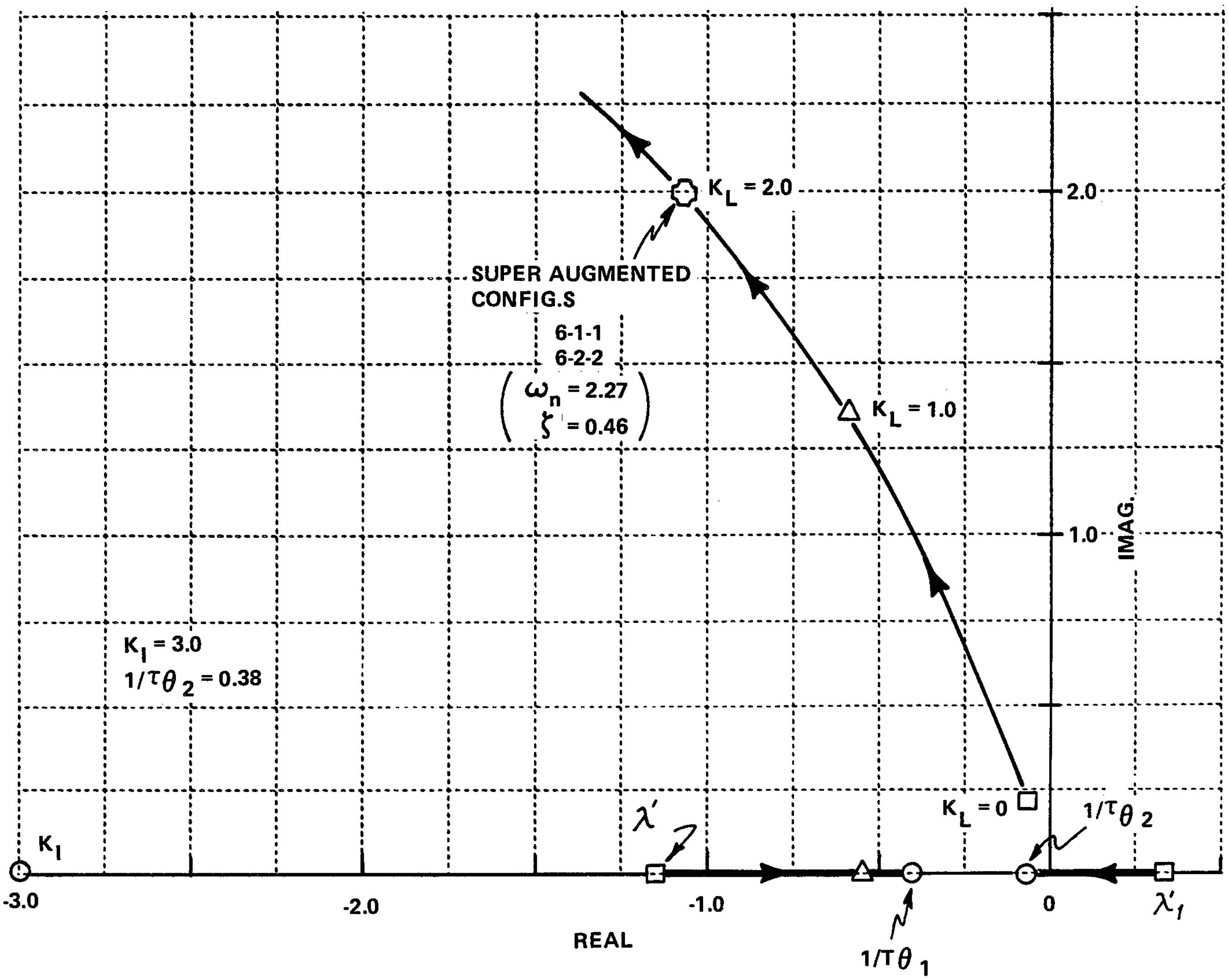


Figure I-6 ROOT LOCUS (CONFIGURATION 6-1-1 & 6-2-2)

(FOR PRE FILTER ROOTS SEE TEXT)

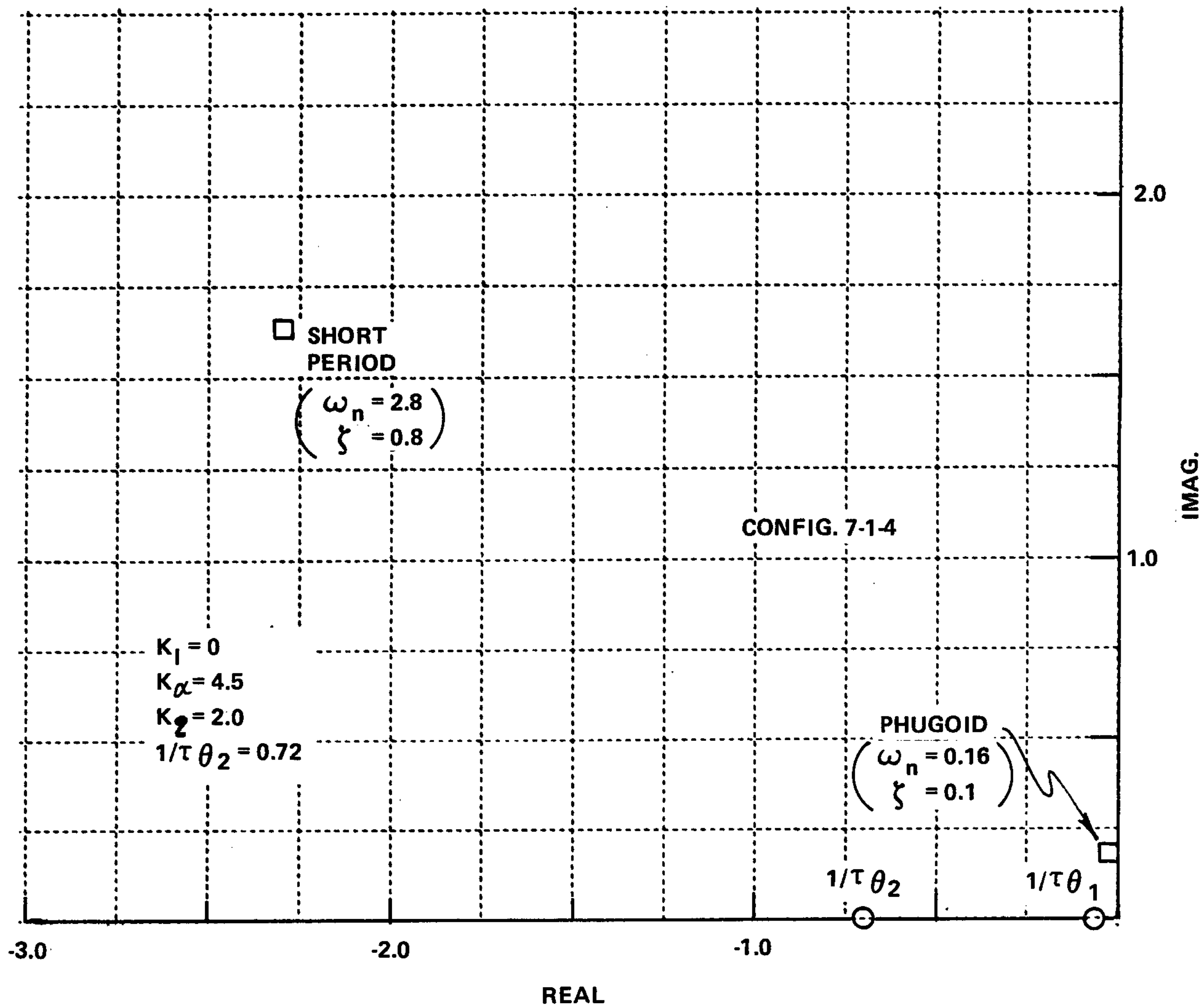


Figure I-7 ROOT LOCUS (CONFIG. 7-1-4

APPENDIX J

RECORDING LIST

PITCH RATE PROGRAM
DIGITAL TAPE RECORDING LIST

Flight # 725 - 744 Date: 1-23 September 1983

VARIABLE DESIGNATION NUMBER	VARIABLE	SOURCE	DIGITAL RECORDING CHANNEL	STRIP CHART NUMBER
	$+.05\ \Delta\theta_{MTCG}$	AMF-35	1	1-1
	$+.5\ \Delta\theta$	A-3s	2	2-1
AUX 45A	$+.5\ q_{I_{MTCG}}$	AMF-2	3	3-1
	$+.5\ q_I$	A-24s	4	4-1
AUX 48A	$+\Delta\ \alpha_{I_{MTCG}}$	AMF-6	5	4-2
	$+\Delta\ \alpha_I$	A-105s	6	3-2
	$+.02\ \Delta P_E$	B-112s	7	
	$+.04\ \Delta V_{IM}$	AMF-34	8	2-2
	$+.04\ \Delta V$	A-90s	9	1-2
AUX 42A	$+.5\ \dot{V}_{MTCG}$	AMF-8	10	2-5
	$+.5\ \dot{V}_T$	A-86s	11	1-5
AUX 53A	$+4\ \Delta N_{Z_{MP/T}}$	AMF-26	12	3-3
	$+4\ \Delta N_{Z_P}$	A-52s	13	4-3
	$+.4\ \delta_{e_{ST}}$	B-106s	14	2-10
	$+0.1\ \dot{h}$	A-80s	15	2-9
AUX 47A	$+.5\ \theta_M$	AMF-27	16	
AUX 50A	$+40 \sin \gamma_{MTCG}$	AMF-25	17	
AUX 50B	$+10\ N_{Y_{MTCG}}$	BMF-11	18	2-3
	$+10\ N_{Y_{TOG}}$	A-40s	19	1-3
AUX 51B	$+.2\ p_{I_{MTCG}}$	BMF-7	20	1-4

PITCH RATE PROGRAM
DIGITAL TAPE RECORDING LIST

VARIABLE DESIGNATION NUMBER	VARIABLE	SOURCE	DIGITAL RECORDING CHANNEL	STRIP CHART NUMBER
	$+.2\ p_I$	A-18s	21	2-4
AUX 49B	$+.1\ \phi_{MTCG}$	BMF-10	22	
	$+.1\ \phi$	A-10s	23	
AUX 54B	$+.5\ V_{IMTCG}$	BMF-8	24	3-4
	$+.5\ r$	A-30s	25	4-4
	$+.4\ \delta_{e_c}$	B-110s	26	3-7
	$+.02\ \Delta P_E$	A-43s	27	4-7
AUX 48B	$+.04\ \Delta V_{IM}$	BMF-9	28	4-5
	$+.04\ \Delta V$	A-130s	29	3-5
	$+.5\ \dot{V}_{MTCG}$	A-170	30	
	$+.5\ \dot{V}_T$	M74,-X	31	
	$+4\ \Delta N_{z_{MP/T}}$	A-83s	32	
	$+4\ \Delta N_{z_p}$	SU-123	33	4-10
	$+.4\ \delta_{e_{ST}}$	SU-122	34	
	$+0.1\ \dot{h}$	SU-168	35	
	$+.5\ \theta_M$	SU-169	36	
	$+40\ \sin\ \gamma_{MTCG}$	BMF-5	37	
	$+10\ N_{y_{MTCG}}$	A-48s	38	
	$+10\ N_{y_{TOG}}$	SU-176	39	
	$+.2\ p_{I_{MTCG}}$	B-123s	40	

PITCH RATE PROGRAM
DIGITAL TAPE RECORDING LIST

VARIABLE DESIGNATION NUMBER	VARIABLE	SOURCE	DIGITAL RECORDING CHANNEL	STRIP CHART NUMBER
	$\Delta N_{z_{MTCG}}$	AMF-7	41	3-9
	$+.25\ \delta_{y_R}$	B-157s	42	3-10
	$.25\ \delta_{A_{STR}}$	B-117s	43	
	$+.25\ \delta_{z_R}$	B-148s	44	1-10
	$+.5\ \delta_r$	B-129s	45	4-8
	$+.25\ \delta_a$	B-118s	46	2-8
	$+.4\ \delta_e$	B-107s	47	1-8
	$+.1\ \delta_{x_R}$	B-177s	48	
SUA 26	$\Delta\delta_{es}$	AMF-39	49	1-7
SUA 8	$+.4\ \delta_{e_c}$	AMF-28	50	2-7
AUX 55B	$+.5\ \delta_{HC}$	BMF-21	51	
SUB 26	$+.1\ \delta_{AS}$	BMF-31	52	3-6
	$+.2\ \delta_{r_p}$	B-91s3	53	3-8
SUA 78	$+.4\ \delta_{RC}$	AMF-30	54	
	$.25\ \delta_{x_{CFF}}$	A-28	55	
	+.1 PLAP	A-147s	56	
SUB 7	$+.4\ \delta_{AC}$	AMF-31	57	4-6
	$+.5\ \alpha_{MTCG}$	AMF-5	58	4-9

PITCH RATE PROGRAM
ON-BOARD STRIP CHART RECORDING LIST

Flight # 725 - 744 Date: 1-23 September 1983

CHANNEL

	1	2	3	4
1	$.5\ \Delta\theta_{MTCG}$ AMF-35	$.5\ \Delta\theta$ A-3s	$.5\ q_{IMTCG}$ AMF-2	$.5\ q_I$ A-24s
2	$.04\ \Delta V$ A-90s	$.04\ \Delta V_{IM}$ AMF-34	$\Delta\alpha_T$ A-105s	$\Delta\alpha_{IMTCG}$ AMF-6
3	$10\ N_{y_{TCG}}$ A-40s	$10\ N_{y_{PM}}$ BMF-5	$4\ \Delta N_{z_{MP/7}}$ AMF-26	$4\ \Delta N_{z_p}$ A-52s
4	$.2\ p_{IMTCG}$ BMF-7	$.2\ p_I$ A-18s	$.5 p_{IMTCG}$ BMF-8	$.5\ p_I$ A-30s
5	$.5\ \dot{V}_I$ A-80s	$.5\dot{V}_{IMTCG}$ AMF-8	$.5\ \beta_I$ A-130s	$.5\ \beta_{MTCG}$ BMF-9
6			$.1\ \delta_{AS}$ BMF-31	$.4\ \delta_{AC}$ B-7
7	$\Delta\delta_{ES}$ AMF-39	$.4\ \delta_{e_c}$ AMF-28	$.4\ \delta_{e_c}$ B-110s	$4\ N_{z_{TCG}}$ A-43s
8	$.25\ \delta_a$ B-118s	$.4\ \delta_e$ B-109s	$2\ \delta_{r_p}$ B-91s	$.2\ \delta_r$ B-129s
9		$+.1\ \dot{h}$ A-80s	$4\ N_{z_{MTCG}}$ AMF-7	$.5\alpha_{MTCG}$ AMF-5
10	$.25\ \delta_z{}^R$ B-148s	$+.4\ \delta_{e_{STR}}$ B-106s	$.25\ \delta_y{}^R$ B-157s	$.05\ h$ LGR + T.D. SU-176

APPENDIX K

ANALYSIS TABLES

Table 1
PILOT RATING BREAKDOWN

CONFIGRUATION	PILOT A HQR (FLT NO.)	PILOT B HQR (FLT NO.)	AVERAGE HQR	COMMENTS
1-1-1	5(735)	7(734)	6.0	q cmd $1/\tau_{\theta_2} = 0.4$
1-2-2	8(731), 7(737)	5.5(733)	6.8	$\omega_n = 2.8$ $1/\tau_{\theta_2} = 0.7$
1-3-7	3(729), 4(737)	7(736)	4.5	$\omega_n = 2.8$ $1/\tau_{\theta_2} = 1.0$
2-1-1	6(729)	5(733), 7(738)	6.0	q cmd $1/\tau_{\theta_2} = 0.4$
2-2-2	4.5(735)	3(736)	3.8	$\omega_n = 1.8$ $1/\tau_{\theta_2} = 0.7$
3-1-3	5.5(737)	6(734)	5.8	neutral static $1/\tau_{\theta_2} = 0.4$
3-2-4	2.5(731)	*4(733),5(738),*4(741)	3.8	neutral static $1/\tau_{\theta_2} = 0.7$
4-1-1	2.5(735)	5(734), *6(741)	3.8	1-1-1 plus lead/lag
4-2-2	2(730)	3(734)	2.5	1-2-2 plus lead/lag
4-3-7	-	7(739)	7.0	1-3-7 plus lead/lag
4-3-7-1	4(743)	-	4.0	4-3-7 plus washout
5-1-1	4.5(729)	4.5(733)	4.5	2-1-1 plus lead/lag
5-2-2	2(729)	3(736)	2.5	2-2-2 plus lead/lag
6-1-1	3(730), 5(737)	6(736, 6(734)	5.0	Super Aug. $1/\tau_{\theta_2}$
6-1-1-1	-	3(739)	3.0	6-1-1 plus washout
6-2-1	5(730), 5(737)	2(736)	3.7	Super Aug. plus lead/lag
6-2-1-1	-	3(739)	3.0	6-2-1 plus washout
7-1-4	3(735)	2.5(738)	2.8	Conv. Aircraft $\omega_n = 2.8$
8-1-5	5.5(742), 4(740)	6(741)	5.2	Shuttle like with lead/lag
8-1-5-1	2(743)	-	2.0	8-1-5 plus washout
8-2-5	8(740), 8(742)	*9(734), 7(741)	7.7	Modified shuttle
8-2-5-1	2(743)	-	7.0	8-2-5 plus washout
8-3-5	5(740), 8(742), 7(744)	7(741)	6.7	Shuttle like OFT
8-3-5-1	3(743), 3(744)	-	3.0	8-3-5 plus washout
8-4-6	1(743)	-	1.0	Shuttle like canard
8-5-5	5(740), 7(742)	-	6.0	8-1-5 plus time delay
8-5-5-1	4(744)	-	4.0	8-5-5 plus washout

* On flights 733 and 741 configurations 3-2-4 and 4-1-1 were dropped due to poor model following, on flight 734 configuration 8-2-5 was dropped due to improper command gain.

Table 2
TIME DOMAIN CRITERIA PARAMETERS
(Pitch Rate Program Data)
For Figures 48 thru 57

CONFIGURATION	α ①	N_{z_p} ②	T_α	$T_{\alpha'}$ ③	HQR	PHQR-1 ④	HQR−PHQR-1	SYMBOL	PHQR-2 ⑤	HQR−PHQR-2
1-1-1	0.44	0.35	1.5	0.6	6.0	5.1	0.9	○	4.5	1.5
1-2-2	0.24	0.33	1.5	0.4	6.8	4.9	1.9	○	4.1	2.7
1-3-7	0.18	0.31	1.3	0.2	4.5	4.3	0.2	○	3.9	0.6
2-1-1	0.35	0.18	2.3	2.2	6.0	5.1	0.9	○	5.4	0.6
2-2-2	0.14	0.15	2.0	1.0	3.8	4.4	-0.6	○	4.5	-0.7
3-1-3	0.53	0.19	2.3	3.1	5.8	5.7	0.1	D	6.2	-0.4
3-2-4	0.38	0.16	2.0	2.0	3.8	5.3	-1.5	D	5.4	-1.6
4-1-1	0.08	1.0	1.0	0	3.8	2.5	1.3	▷	2.6	1.2
4-2-2	0.11	0.52	1.0	0	2.5	3.5	-1.0	▷	3.3	-0.8
4-3-7	0.07	0.36	1.0	0	*7.0	3.7	*3.3	▷	3.5	*3.5
4-3-7-1	0	0.45	1.0	0	4.0	3.3	0.7	◇	3.3	0.7
5-1-1	0.12	0.40	1.3	0.1	4.5	3.9	0.6	▷	3.6	0.9
5-2-2	0.13	0.30	1.5	0.3	2.5	4.1	-1.6	▷	3.9	-1.4
6-1-1	0.30	0.20	2.0	1.4	5.0	4.9	0.1	○	4.9	0.1
6-1-1-1	0.03	0.30	2.0	0.2	3.0	3.7	-0.7	□	3.6	-0.6
6-2-1	0.10	0.67	1.0	0	3.7	3.2	0.5	▷	3.1	0.6
6-2-1-1	0	0.87	1.0	0	3.0	2.5	0.5	◇	2.7	0.3
7-1-4	0.04	0.67	1.0	0	2.8	3.0	-0.2	×	3.0	-0.2
8-1-5	0	-0.17	2.0	0.2	5.2	4.6	0.6	▷	4.3	0.9
8-1-5-1	0.20	-0.20	1.5	0.5	2.0	5.4	-3.4	◇	4.8	-2.8
8-2-5	0.19	-0.08	2.8	3.3	7.7	5.1	2.6	○	6.1	1.6
8-2-5-1	-0.19	-0.10	2.5	2.4	*7.0	3.1	*3.9	□	4.6	*2.4
8-3-5	0.17	-0.10	2.3	1.9	6.7	5.1	1.6	○	5.4	1.3
8-3-5-1	-0.17	-0.11	2.3	1.8	3.0	3.9	-0.9	□	4.8	-1.8
8-4-6	0.19	1.2	2.3	0.2	1.0	2.5	-1.5	○	2.6	-1.6
8-5-5	0	-0.17	2.0	0.2	6.0	4.6	1.4	▷	4.3	1.7
8-5-5-1	0	-0.20	1.5	0.1	4.0	4.7	-0.7	◇	4.3	-0.2

① $\dot{\alpha}' = \dot{\alpha}_{ss_1} / \dot{\alpha}_I$

② $N'_{z_p} = N_{z_{p_I}} / N_{z_{p_{max}}}$

* Suspect data points, see text.

③ $T'_\alpha = |T_\alpha - 1.0| \left[\dfrac{|\dot{\alpha}'| + 0.5}{|N'_{z_p}| + 0.5} \right]$

④ $PHQR\text{-}1 = 3.6\,\dot{\alpha}' - 2.0\,N'_{z_p} + 4.3$

⑤ $PHQR\text{-}2 = 1.7\,\dot{\alpha}' - 1.44\,N'_{z_p} + 0.55\,T'_\alpha + 3.9$

Table 3
TIME DOMAIN CRITERIA PARAMETERS
(Large Aircraft Data)
For Figures 51 thru 57

CONFIGURATION	α ③	N_{z_p} ④	T_α	$T_{\alpha'}$ ⑤	HQR	$PHQR_1$ ⑥	HQR − $PHQR_1$	SYMBOL	$PHQR_2$ ⑦	HQR − $PHQR_2$
① LAT (lo α)	0.67	0.24	4.0	6.0	5.0	6.1	-1.1	○	8.0	-3.0
LAT (med α)	0.41	0.30	4.0	3.3	6.0	5.3	0.7	○	6.1	-0.1
LAT (hi α)	0.17	0.43	3.2	1.0	4.3	4.0	0.3	○	4.1	0.2
LAT (ex hi α)	0.08	0.70	3.0	0.3	5.0	3.1	1.9	○	3.2	1.8
LAT (N/α = 3)	0.08	0.58	3.5	0.5	5.3	3.3	2.0	○	3.5	1.8
LAT (lo q)	1.0	0.09	6.0	6.0	9.0	7.6	1.4	○	8.8	0.2
LAT (med q)	0.42	0.21	4.0	5.4	4.5	5.3	-0.8	○	7.3	-2.8
LAT (hi q)	0.27	0.50	3.0	1.2	3.1	4.2	-1.1	○	4.3	-1.2
CANARD (med α)	0.38	0.50	3.5	2.3	4.5	4.6	-0.1	⬡	5.1	-0.6
CANARD (hi α)	0.16	0.75	3.5	0.7	4.0	3.3	0.7	⬡	3.5	0.5
CANARD (hi q)	0.36	0.70	3.0	1.1	3.0	4.1	-1.1	⬡	4.5	-1.1
② SAT (med α)	0.43	0	3.5	6.0	10.0	5.8	4.2	□	7.9	2.1
SAT (hi α)	0.20	0	3.0	6.0	9.0	5.0	4.0	□	7.5	1.5
SAT (med α)	0.42	0	4.5	6.0	9.0	5.8	-3.3	□	7.9	1.1
SAT (hi q)	0.28	0	3.0	6.0	6.0	5.3	0.8	□	7.7	-1.7
SAT (ex hi q)	0.21	-0.08	1.8	1.6	4.0	5.2	-1.2	□	5.3	-1.3

Notes:

- Configurations with time delay in excess of 150 ms were not used.
- LAT (N_Z/α = 0) and Canard (ex hi α) not used (rating based on approach).
- Canard (lo α) not used (discontinuity between pilot comments and rating).

① LAT = Long Aft Tail
② SAT = Short Aft Tail

③ $\dot{\alpha}' = \dot{\alpha}_{ss_1} / \dot{\alpha}_I$

④ $N'_{z_p} = N_{z_{p_I}} / N_{z_{p_{max}}}$

(If $T'_\alpha > 6.0$ let $T'_\alpha = 6.0$)

⑤ $T'_\alpha = |T_\alpha - 1.0| \left[\dfrac{|\dot{\alpha}'| + 0.5}{|N'_{z_p}| + 0.5} \right]$

⑥ $PHQR\text{-}1 = 3.6\ \dot{\alpha}' - 2.0\ N'_{z_p} + 4.3$

⑦ $PHQR\text{-}2 = 1.7\ \dot{\alpha}' - 1.44\ N'_{z_p} + 0.55\ T'_\alpha + 3.9$

Table 4
TIME DOMAIN CRITERIA PARAMETERS
(SST Data)
For Figures 56 thru 57

CONFIGURATION	α ①	N_{z_p} ②	T_α	$T_{\alpha'}$ ③	HQR	$PHQR_1$ ④	HQR − $PHQR_1$	SYMBOL	$PHQR_2$ ⑤	HQR − $PHQR_2$
1	0	0.36	3.5	0.3	3.0	3.6	-0.6	○	3.5	-0.5
13	0.06	0.50	3.0	0.4	2.8	3.5	-1.5	○	3.5	-1.5
20	0.08	0.50	3.0	0.47	3.5	3.6	-0.1	○	3.6	-0.1

Note: All configurations except 1, 13, and 20 were unstable and had divergent time histories, consequently time domain criteria was not applicable.

① $\dot{\alpha}' = \dot{\alpha}_{ss_1} / \dot{\alpha}_I$

② $N'_{z_p} = N_{z_{p_I}} / N_{z_{p_m}}$

③ $T'_\alpha = |T_\alpha - 1.0| \left[\dfrac{|\dot{\alpha}'| + 0.5}{|N'_{z_p}| + 0.5} \right]$

④ $PHQR\text{-}1 = 3.6\, \dot{\alpha}' - 2.0\, N'_{z_p} + 4.3$

⑤ $PHQR\text{-}2 = 1.7\, \dot{\alpha}' - 1.44\, N'_{z_p} + 0.55\, T'_\alpha + 3.9$

Time histories did not include $N_{z_{p_I}}$, it was calculated by:

$$N_{z_{p_I}} = N_{z_{I_{CG}}} - \frac{\dot{q}_m}{57.39}(X_{mp})$$

$$= -0.018 - \frac{(0.64)(125)}{57.3(32.2)}$$

$$= +0.025$$

where: $\dot{q}_m = 0.64$ deg/sec

$N_{z_{I_{CG}}} = -0.018$ g

$X_{mp} = 125$ ft

Table 5
AVERAGED COOPER-HARPER RATINGS AND LEVELS
FOR FLIGHT DATA

CONFIGURATION	AVERAGE C-H RATING	LEVEL
1-1-1	6.0	2-3
1-2-2	6.8	2-3
1-3-7	4.5	2
2-1-1	6.0	2
2-2-2	3.5	1-2
3-1-3	5.8	2
3-2-4	3.8	1-2
4-1-1	3.8	1-2
4-2-2	2.5	1
4-3-7	7.0	3
4-3-7-1	4.0	1-2
5-1-1	4.5	2
5-2-2	2.5	1
6-1-1	4.6	2
6-1-1-1	3.0	1
6-2-1	3.5	1-2
6-2-1-1	3.0	1
7-1-4	2.8	1
8-1-5	4.8	2
8-1-5-1	2.0	1
8-2-5	7.5	3
8-2-5-1	7.0	3
8-3-5	7.3	3
8-3-5-1	3.0	1
8-4-6	1.0	1
8-5-5	6.0	2
8-5-5-1	4.0	1-2

HQR 1.0 - 3.0 = Level 1
HQR 3.0 - 4.0 = Level 1-2
HQR 4.0 - 6.0 = Level 2
HQR 6.0 - 7.0 = Level 2-3
HQR 7.0 - 10.0 = Level 3

Table 6
LOWER ORDER EQUIVALENT SYSTEMS ANALYSIS

($\dot{\theta}$ Match, L_α Fixed)

CONFIG.	$1/\tau_{\theta_2}$	ω_{sp}	LEVEL	ζ_{sp}	LEVEL	$\tau_{\dot{\theta}}$	LEVEL	OVERALL LEVEL	COST FUNCTION
1-1-1	0.40	1.51	1	1.45	2	0.194	2	2	8.9
1-2-2	0.72	1.96	1	1.08	1	0.188	2	2	3.5
1-3-7	1.00	2.21	1	0.94	1	0.173	2	2	1.6
2-1-1	0.40	1.07	1	0.81	1	0.186	2	2	21.7*
2-2-2	0.72	1.33	1	0.65	1	0.181	2	2	9.0
3-1-3	0.40	1.00	1	1.45	2	0.175	2	2	9.0
3-2-4	0.72	0.27	3	1.46	2	0.330	3	3	184.0*
4-1-1	0.40	2.84	1-2	0.80	1	0.183	2	2	0.70
4-2-2	0.72	2.81	1	0.80	1	0.181	2	2	0.24
4-3-7	1.00	2.52	1	0.88	1	0.171	2	2	0.92
4-3-7-1	1.00	2.63	1	0.70	1	0.150	2	2	40.2*
5-1-1	0.40	1.78	1	0.63	1	0.176	2	2	2.40
5-2-2	0.72	1.76	1	0.60	1	0.172	2	2	0.80
6-1-1	0.40	1.14	1	0.82	1	0.208	2-3	2-3	71.0*
6-1-1-1	0.40	1.40	1	0.62	1	0.192	2	2	53.0*
6-2-1	0.40	2.29	1	0.47	1	0.74	2	2	1.2
6-2-1-1	0.40	2.41	1	0.34	1-2	0.099	1-2	1-2	257.0*
7-1-4	0.72	2.80	1	0.90	1	0.166	2	2	7.0
8-1-5	0.40	1.43	1	0.57	1	0.173	2	2	5.4
8-1-5-1	0.40	1.54	1	0.45	1	0.158	2	2	33.2*
8-2-5	0.40	0.97	1	0.49	1	0.171	2	2	8.1
8-2-5-1	0.40	1.06	1	0.39	1	0.159	2	2	15.2
8-3-5	0.40	1.04	1	0.65	1	0.228	3	3	21.3*
8-3-5-1	0.40	1.17	1	0.51	1	0.216	3	3	16.0
8-4-6	0.40	1.44	1	0.64	1	0.173	2	2	4.7
8-5-5	0.40	1.17	1	0.52	1	0.208	2-3	2-3	6.2
8-5-5-1	0.40	1.23	1	0.42	1	0.184	2	2	17.4

n_z/α = 2.6 ($1/\tau_{\theta_2}$ = 0.4), 5.0 (0.72), 6.9 (1.0)

* Poor Fit

Table 7
BANDWIDTH CRITERION RESULTS
(Category C Flight Phase)

CONFIG.	τ_p	ω_{BWG}	$\omega_{BW\phi}$	LEVEL
1-1-1	0.135	2.49	2.19	2
1-2-2	0.135	2.49	2.20	2
1-3-7	0.135	2.49	2.21	2
2-1-1	0.140	1.76	1.46	2
2-2-2	0.141	1.76	1.48	2
3-1-3	0.124	2.32	1.47	2
3-2-4	0.123	2.32	1.46	2
4-1-1	0.137	3.00	3.07	2
4-2-2	0.137	2.85	2.86	2
4-3-7	0.137	2.61	2.46	2
4-3-7-1	0.133	2.78	2.63	2
5-1-1	0.136	2.38	2.05	2
5-2-2	0.134	2.19	1.86	2
6-1-1	0.167	1.54	1.77	2
6-1-1-1	0.161	1.75	1.89	2
6-2-1	0.137	2.64	2.51	2
6-2-1-1	0.136	2.76	2.59	2
7-1-4	0.132	2.97	2.95	2
8-1-5	0.133	2.05	1.66	2
8-1-5-1	0.131	2.18	1.77	2
8-2-5	0.136	1.41	1.12	2
8-2-5-1	0.130	1.58	1.22	2
8-3-5	0.267	1.12	1.12	3
8-3-5-1	0.256	1.27	1.30	3
8-4-6	0.131	2.13	1.70	2
8-5-5	0.187	1.73	1.57	3
8-5-5-1	0.183	1.85	1.66	3

Table 8
ALTITUDE RATE BANDWIDTH RESULTS

CONFIGURATION	$\dot{h}_p/F_{es}\omega_{BW}$
1-1-1	0.529
1-2-2	0.709
1-3-7	0.860
2-1-1	0.518
2-2-2	0.677
3-1-3	0.427
3-2-4	0.549
4-1-1	1.08
4-2-2	1.09
4-3-7	0.969
4-3-7-1	1.15
5-1-1	0.903
5-2-2	0.909
6-1-1	0.533
6-1-1-1	0.715
6-2-1	1.19
6-2-1-1	1.33
7-1-4	1.07
8-1-5	0.76
8-1-5-1	0.89
8-2-5	0.585
8-2-5-1	0.706
8-3-5	0.523
8-3-5-1	0.671
8-4-6	3.40
8-5-5	0.748
8-5-5-1	0.875

Table 9
COMPARISON OF FLIGHT DATA WITH VARIOUS PREDICTIVE CRITERIA
(Flying Qualities Levels)

CONFIG.	FLIGHT DATA HQR	FLIGHT DATA	BANDWIDTH CRITERIA (on θ)	EQUIV. SYSTEMS CRITERIA	NEAL-SMITH CRITERIA (on θ)	BANDWIDTH CRITERIA (on ḣ)	TIME DOMAIN CRITERIA
1-1-1	6.0	2-3	2(0)	2(0)	1(=)	3	2(0)
1-2-2	6.8	2-3	2(0)	2(0)	1(=)	-	2(0)
1-3-7	4.5	2	2(+)	2(+)	1(-)	1-2(0)	1-2
2-1-1	6.0	2	2(+)	2(+)	1-2(0)	3(-)	2(+)
2-2-2	3.8	1-2	2(0)	2(0)	1-2(+)	3(-)	2(0)
3-1-3	5.8	2	2(+)	2(+)	1(-)	3(-)	2-3(0)
3-2-4	3.8	1-2	2(0)	3(-)	1(-)	3(-)	2(0)
4-1-1	3.8	1-2	2(0)	2(0)	-	1(0)	1(0)
4-2-2	2.5	1	2(-)	2(-)	1(+)	1(+)	1-2(0)
4-3-7	7.0	3	2(-)	2(-)	1(=)	1-2(-)	1-2(-)
4-3-7-1	4.0	2	2(+)	2(+)	1(+)	1(0)	1-2(0)
5-1-1	4.5	2	2(+)	2(+)	2(+)	1-2(0)	1-2(0)
5-2-2	2.5	1	2(-)	2(-)	1(+)	1-2(0)	1-2(0)
6-1-1	5.0	2	2(+)	2-3	1(-)	3(-)	2(+)
6-1-1-1	3.0	1	2(-)	2(-)	1(+)	2-3(=)	1-2(0)
6-2-1	3.7	1-2	2(0)	2(0)	-	1(0)	1-2(+)
6-2-1-1	3.0	1	2(-)	1-2	-	1(+)	1(+)
7-1-4	2.8	1	2(-)	2(-)	1(+)	1(+)	1(+)
8-1-5	5.2	2	2(+)	2(+)	1-2(0)	2(+)	2(+)
8-1-5-1	2.0	1	2(-)	2(-)	2-3(=)	1-2(0)	2(-)
8-2-5	7.7	3	2(-)	2(-)	2(-)	3(+)	2-3(0)
8-2-5-1	7.0	3	2(-)	2(-)	1(=)	-	2(-)
8-3-5	6.7	3	3(+)	3(+)	2(-)	3(+)	3(0)
8-3-5-1	3.0	1	3(=)	3(=)	2(-)	3(=)	2(-)
8-4-6	1.0	1	2(-)	2(-)	1-2(0)	1(+)	1(+)
8-5-5	6.0	2	3(-)	2-3	2(+)	2(+)	2(+)
8-5-5-1	4.0	2	3(-)	2(0)	2-3(-)	1-3(+)	2(+)

	No./%				
No Grade	0/0	0/0	3/11%	2/7%	0/0
Error = 2 Levels (=)	1/4%	1/4%	4/17%	2/8%	0/0
Error = 1 Level (-)	13/48%	11/41%	8/33%	6/24%	4/15%
Error < 1 Level (0)	6/22%	9/33%	5/19%	8/32%	14/52%
Error = 0 Level (+)	7/26%	6/22%	7/29%	9/36%	9/33%
Total < 1 Level Error	48%	55%	48%	68%	85%

HQR 1.0 - 3.0 = Level 1
HQR 3.0 - 4.0 = Level 1-2
HQR 4.0 - 6.0 = Level 2
HQR 6.0 - 7.0 = Level 2-3
HQR 7.0 - 10.0 = Level 3

Appendix L
MODEL FOLLOWING CONTROL ALGORITHMS

The control algorithms in use for the pitch rate criteria investigation are specified below in terms of linear gains. Some of these gains were fixed, some varied inversely with model indicated airspeed, V_{i_m} (kts), some varied inversely with model true airspeed, V_{T_m}(fps), and some varied inversely with model dynamic pressure, $\bar{q}_m$(psf).

The error gains multiply the difference between model motions at the TIFS center of gravity and TIFS motions - for example $\varepsilon_\beta = \beta_{MF} - \beta$.

These gains were as follows:

$$\frac{\delta_e}{\varepsilon_q} = -2.18 \; \frac{132^2}{V_{i_m}^2} \; , \; \text{sec}$$

$$\frac{\delta_e}{\varepsilon_\theta} = -5.45 \; \frac{132^2}{V_{i_m}^2} \; , \; \text{—}$$

$$\frac{\delta_e}{\int\varepsilon_\theta} = -2.73 \; \frac{132^2}{V_{i_m}^2} \; , \; \text{sec}^{-1}$$

$$\frac{\delta_a}{\varepsilon_p} = -2.80 \left(\frac{132}{V_{i_m}}\right) , \; \text{sec}$$

$$\frac{\delta_a}{\varepsilon_\phi} = -3.94 \left(\frac{132}{V_{i_m}}\right) , \; \text{—}$$

$$\frac{\delta_r}{\varepsilon_r} = 0$$

$$\frac{\delta_r}{\varepsilon_\beta} = 15.14 \left(\frac{132}{V_{i_m}}\right) , \; \text{—}$$

$$\frac{\delta_r}{\varepsilon_{\dot\beta}} = 3.03 \left(\frac{132}{V_{i_m}}\right) , \; \text{sec}$$

$$\frac{\delta_z}{\varepsilon_{\dot\alpha}} = -1.20 \left(\frac{132}{V_{i_m}}\right) , \; \text{sec}$$

$$\frac{\delta_z}{\varepsilon_\alpha} = -8.06 \left(\frac{132}{V_{i_m}}\right) , \; \text{—}$$

$$\frac{\delta_x}{\varepsilon_{\dot V}} = 4.13 \; \frac{132^2}{V_{i_m}^2} \; , \; \%/\text{fps}^2$$

$$\frac{\delta_x}{\varepsilon_V} = 9.07 \; \frac{132^2}{V_{i_m}^2} \; , \; \%/\text{fps}$$

$$V_{i_m} = 132 \text{ kts at trim}$$

The feedforward gains were as follows:

$$\frac{\delta_e}{\dot{q}_{MF}} = -.43\ \frac{59.4}{\bar{q}_m}\ ,\ \sec^2 \qquad \frac{\delta_r}{p_{MF}} = -1.03\ \frac{b}{2V_{T_m}}\ ,\ \sec$$

$$\frac{\delta_e}{\alpha_{MF}} = -.23\ ,\ \text{—} \qquad \frac{\delta_z}{n_{z_{MF}}} = -67.7\ \frac{59.4}{\bar{q}}\ ,\ \text{deg/g}$$

$$\frac{\delta_e}{\delta_{z_{CFF}}} = -.08\ ,\ \text{—} \qquad \frac{\delta_z}{\alpha_{MF}} = -7.16\ ,\ \text{—}$$

$$\frac{\delta_e}{q_{MF}} = -16.5\ \frac{c}{2V_{T_m}}\ ,\ \sec \qquad \frac{\delta_z}{\delta_{e_{CFF}}} = -.84\ ,\ \text{—}$$

$$\frac{\delta_e}{\dot{\alpha}_{MF}} = -6.21\ \frac{c}{2V_{T_m}}\ ,\ \sec \qquad \frac{\delta_x}{\dot{V}_{MF}} = 8.2\ ,\ \%/\text{fps}^2$$

$$\frac{\delta_a}{\dot{p}_{MF}} = -.99\ \frac{59.4}{\bar{q}_m}\ ,\ \sec^2 \qquad \frac{\delta_x}{\sin\gamma_{MF}} = 263.\ ,\ \%/\text{—}$$

$$\frac{\delta_a}{\beta_{MF}} = -1.70\ ,\ \text{—} \qquad \frac{\delta_x}{\bar{q}_m} = .137\ ,\ \%/\text{psf}$$

$$\frac{\delta_a}{r_{MF}} = -3.13\ \frac{b}{2V_{T_m}}\ ,\ \sec \qquad \frac{\delta_x}{\alpha_{MF}} = 1.97\ \frac{\bar{q}}{59.4}\ ,\ \%/\text{deg}$$

$$\frac{\delta_a}{p_{MF}} = -8.80\ \frac{b}{2V_{T_m}}\ ,\ \sec \qquad \frac{\delta_y}{n_{y_{MF}}} = 142.1\ \frac{59.4}{\bar{q}}\ ,\ \text{deg/g}$$

$$\frac{\delta_a}{\delta_{r_{CFF}}} = -.19\ ,\ \text{—} \qquad \frac{\delta_y}{\beta_{MF}} = 3.04\ ,\ \text{—}$$

$$\frac{\delta_r}{\dot{r}_{MF}} = -.71\ \frac{59.4}{\bar{q}_m}\ ,\ \sec \qquad \frac{\delta_y}{r_{MT}} = -.38\ \frac{b}{2V_{T_m}}\ ,\ \sec$$

$$\frac{\delta_r}{\beta_{MF}} = .89 \quad , \text{—} \qquad \frac{\delta_y}{\delta_{r_{CFF}}} = -.63 \quad , \text{—}$$

$$\frac{\delta_r}{r_{MF}} = -1.26 \frac{b}{2V_{T_m}} \quad , \text{sec} \qquad \frac{\delta_y}{\delta_{a_{CFF}}} = .03 \quad , \text{—}$$

$\bar{q}_m$ = 59.4 psf at trim

V_{T_m} = 223 fps at trim

c = 9.52 ft

b = 105.3 ft

CFF signifies the feedforward part of the command signal

APPENDIX M

COMPLETE SET OF FIGURES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

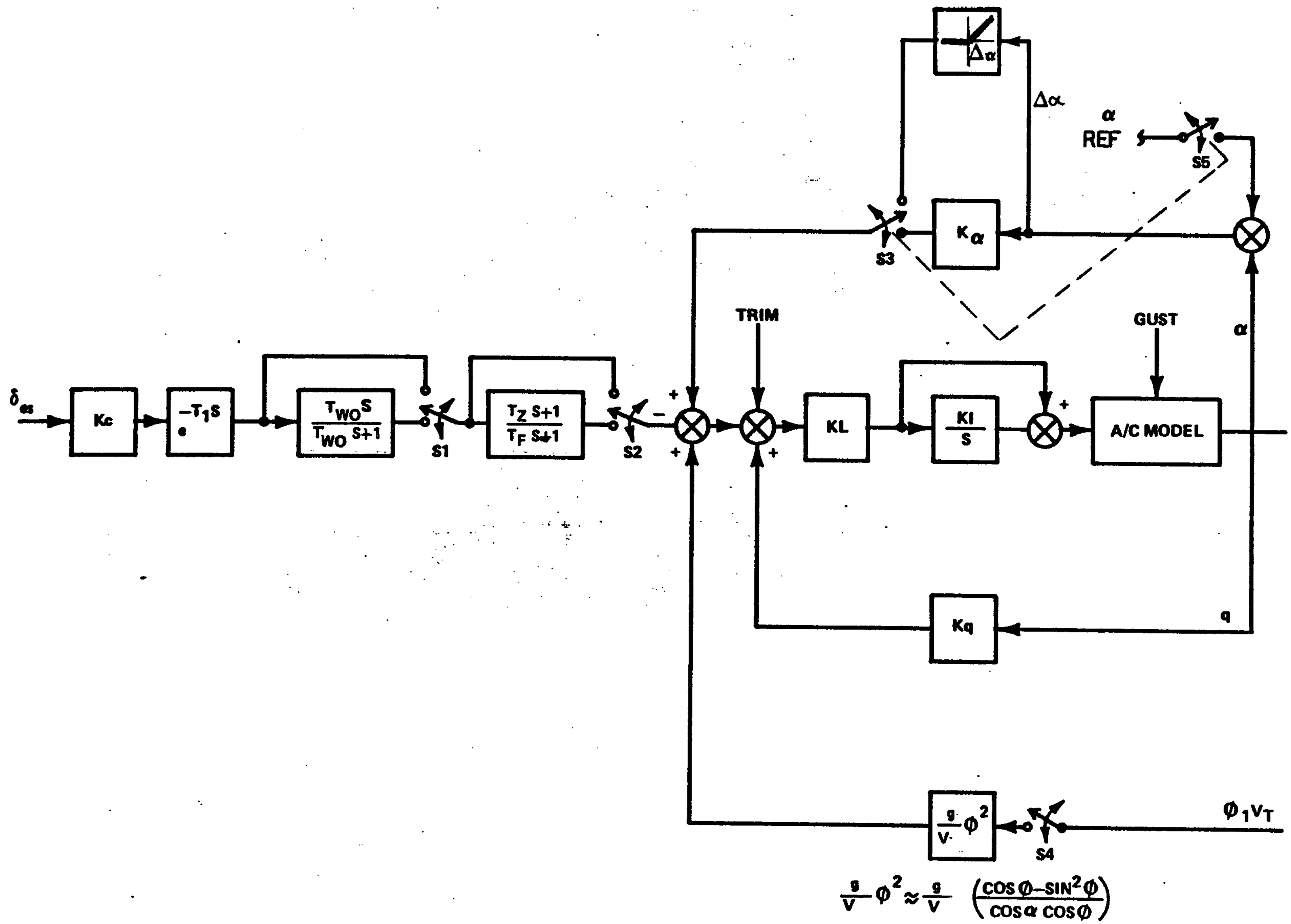


Figure 1 PITCH RATE CRITERIA FLIGHT CONTROL SYSTEM

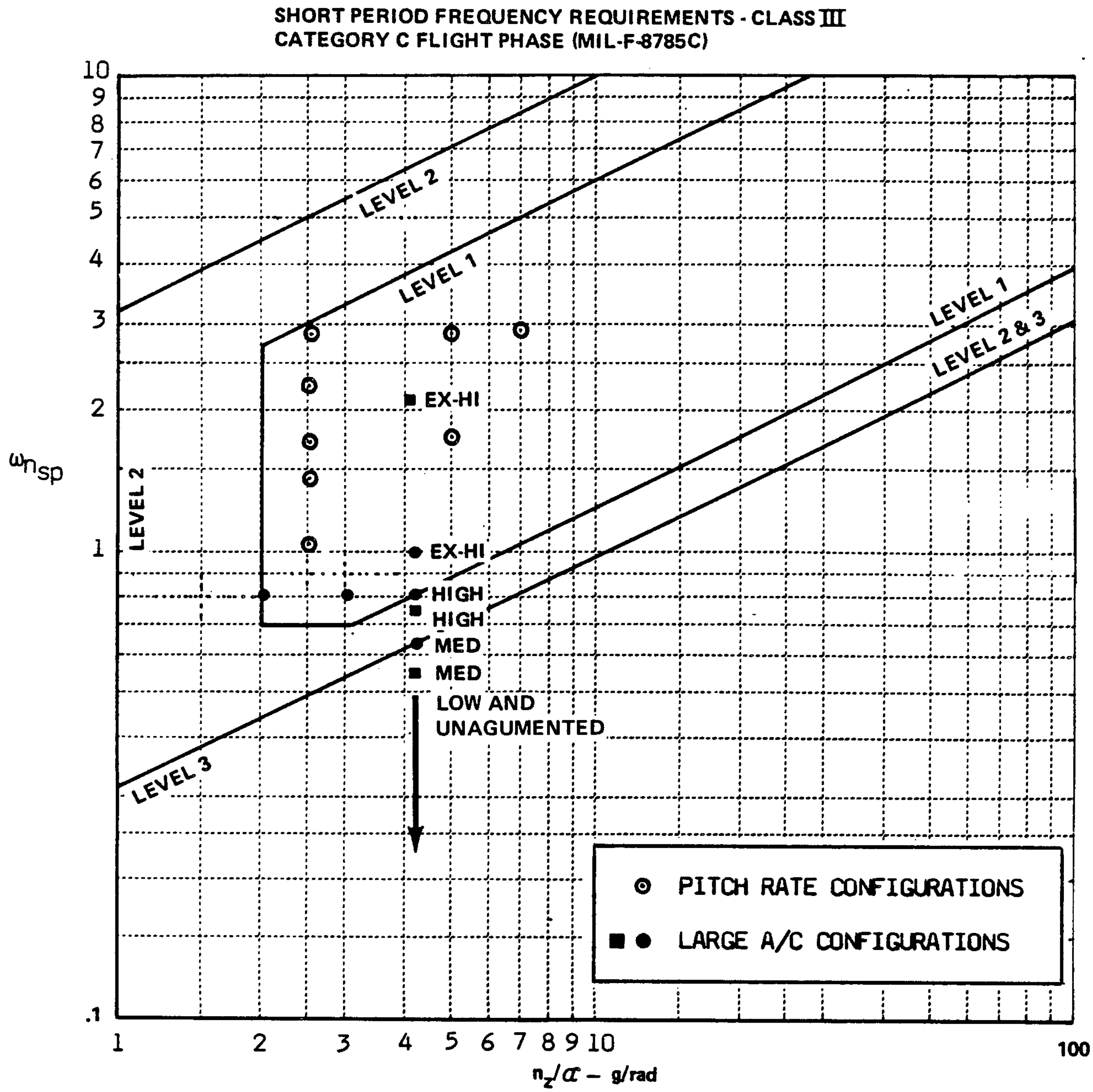


Figure 2 AUGMENTATION LEVELS VS ω_{SP} REQUIREMENTS - NOMINAL ROOTS

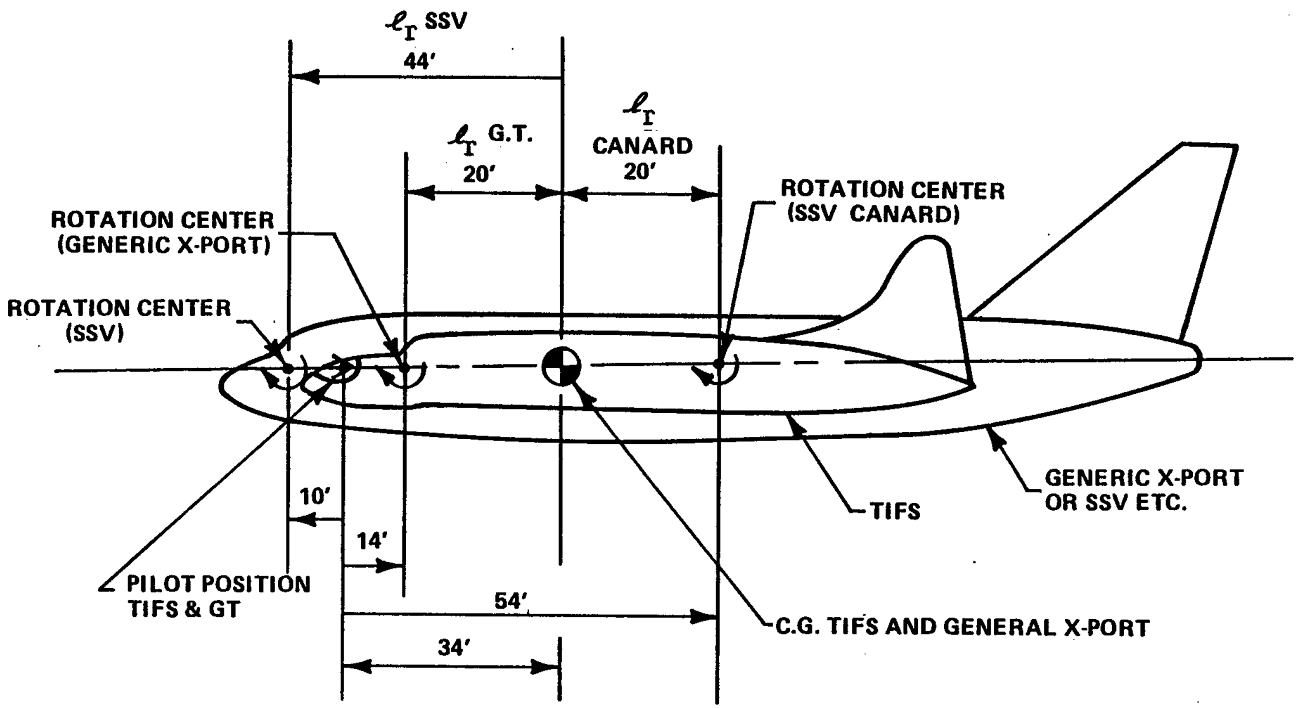


Figure 3 SIMULATION GEOMETRY

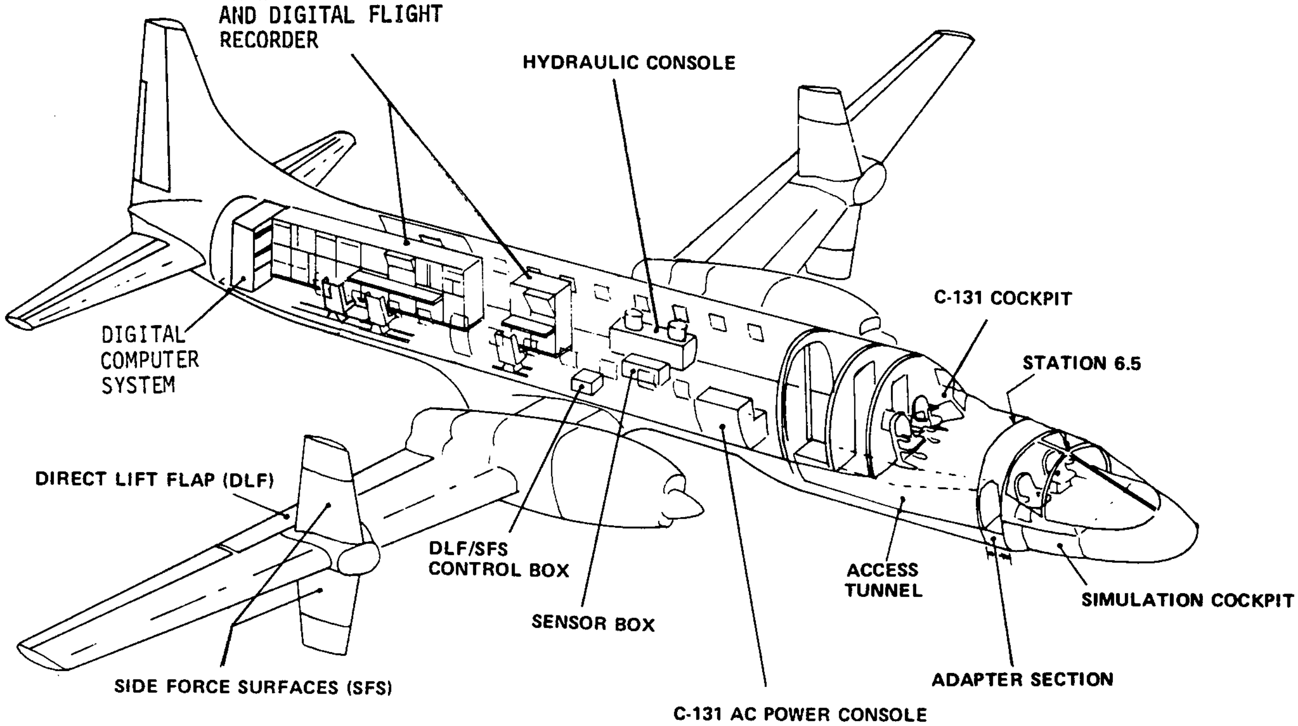


Figure 4 USAF TOTAL IN-FLIGHT SIMULATOR (TIFS)

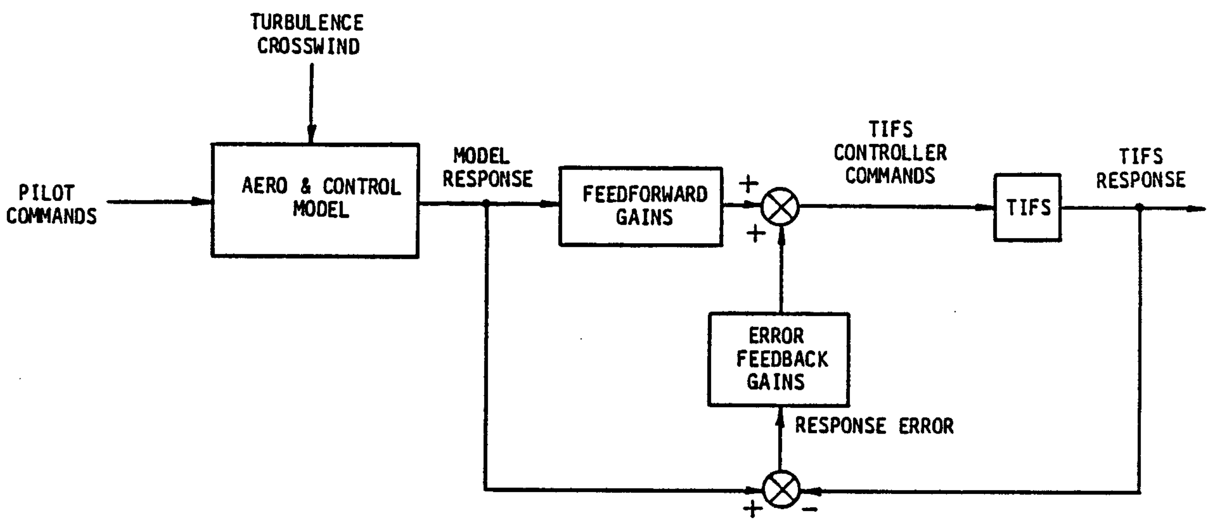


Figure 5 TIFS MODEL FOLLOWING SIMULATION

Figure 6 TIFS EVALUATION COCKPIT

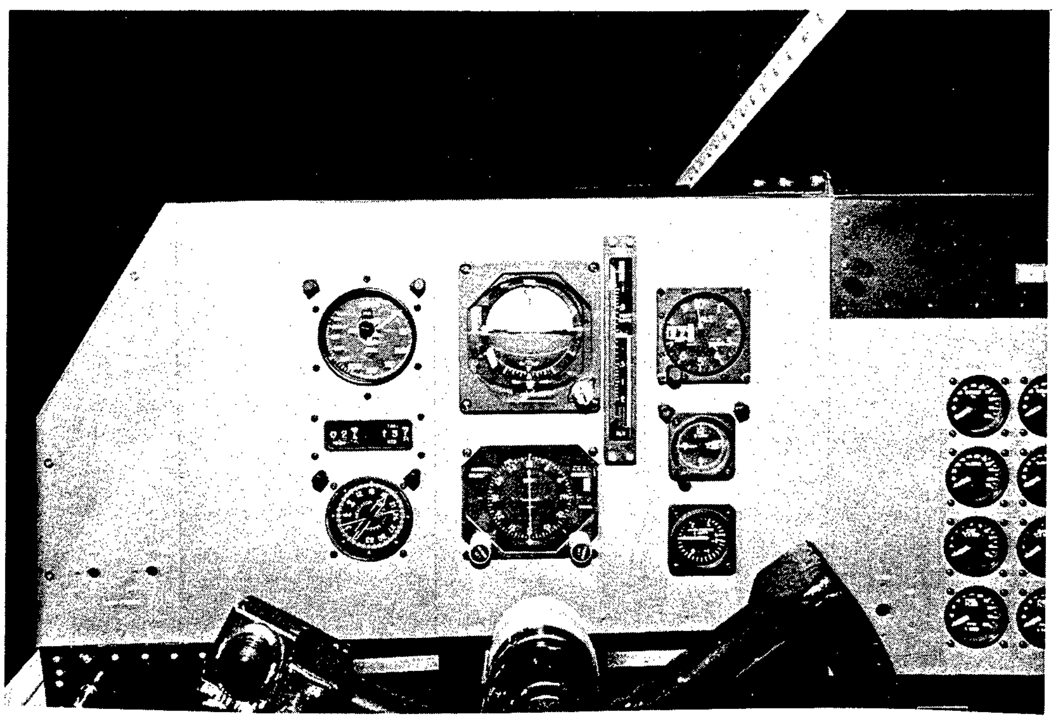


Figure 7 CAPTAIN'S INSTRUMENT PANEL IN EVALUATION COCKPIT

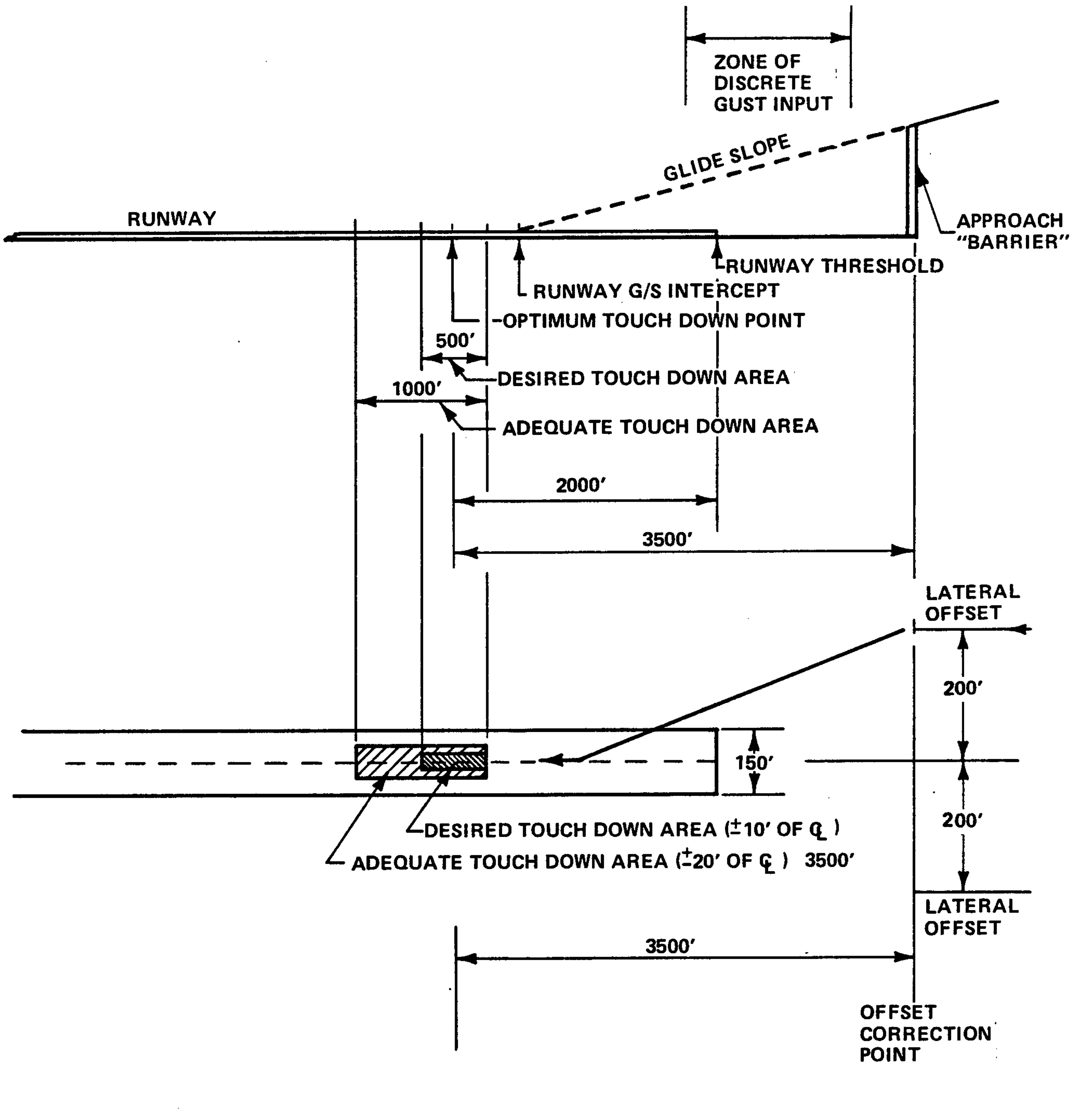


Figure 8 APPROACH AND LANDING TASK

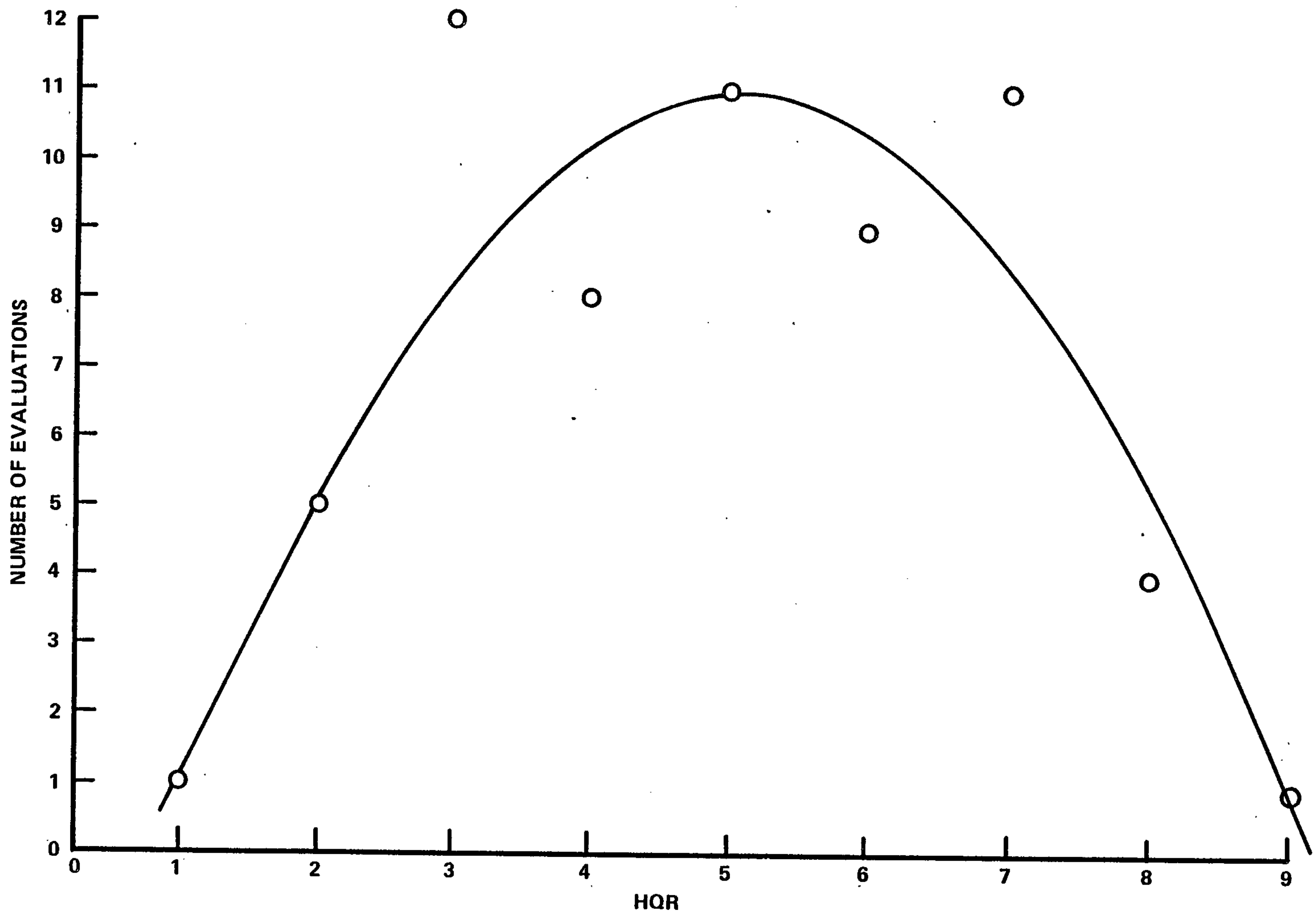


Figure 9 PITCH RATE INVESTIGATION HQR DISTRIBUTION

PILOT COMMENT CARD

1. Feel
   - Column, wheel forces and displacements, harmony
   - Roll and pitch sensitivity

2. Response to inputs <u>required to perform task</u>
   - Roll and pitch
     - initial response
     - predictability of final response
     - pitch/roll harmony
     - special pilot inputs - why?
     - tendency to PIO
     - sensitivity (gearing)

3. Airspeed control (autothrottle OFF)

4. Approach performance
   - ILS: glideslope, localizer capture and tracking
   - Visual: flight path corrections

5. Flare and touchdown
   - Problems with line-up flare, touchdown, tendency to float
   - Any unusual motions, visual cues, etc.
   - Any unusual control techniques required

6. Approach vs. landing
   - Which more difficult

7. Effects of turbulence/wind

8. Summary (brief)
   - Good features
   - Problems

9. Overall Cooper-Harper Rating - PIO Rating

Figure 10 PILOT COMMENT CARD

HANDLING QUALITIES RATING SCALE

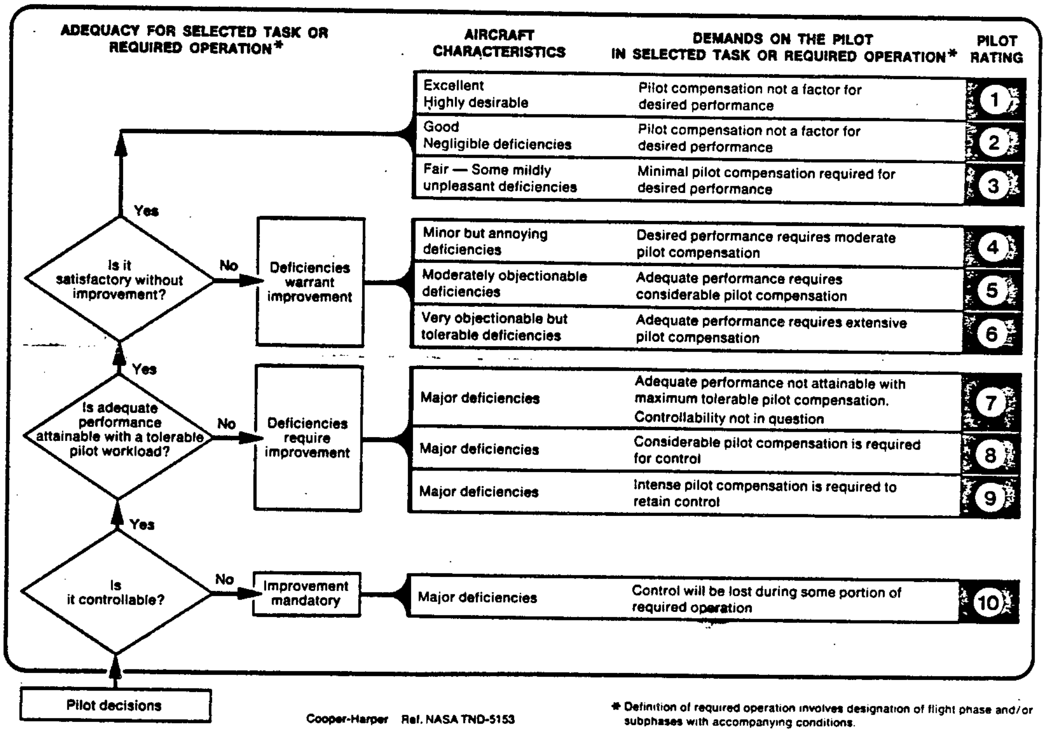


Figure 11 COOPER-HARPER HANDLING QUALILTIES RATING SCALE

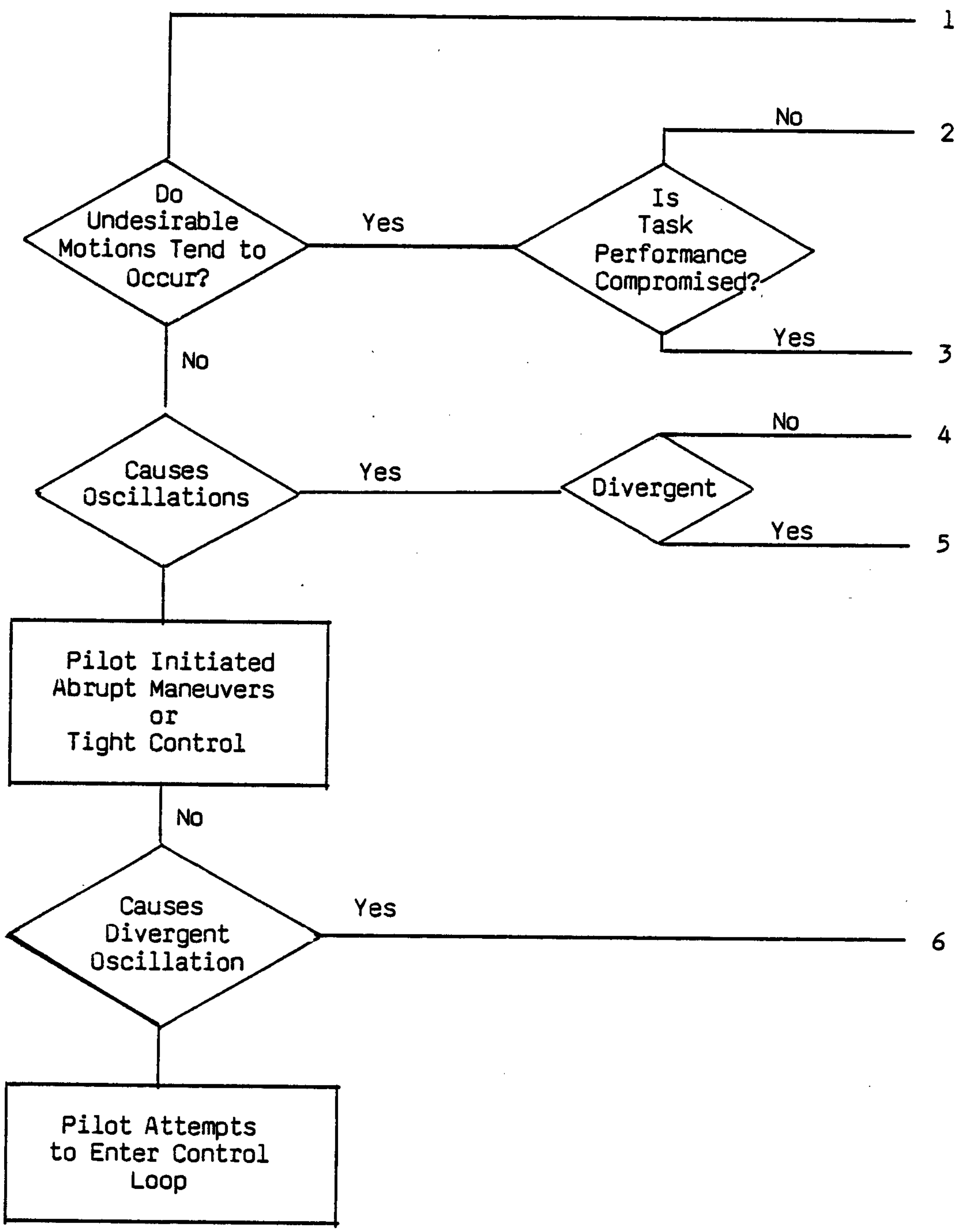
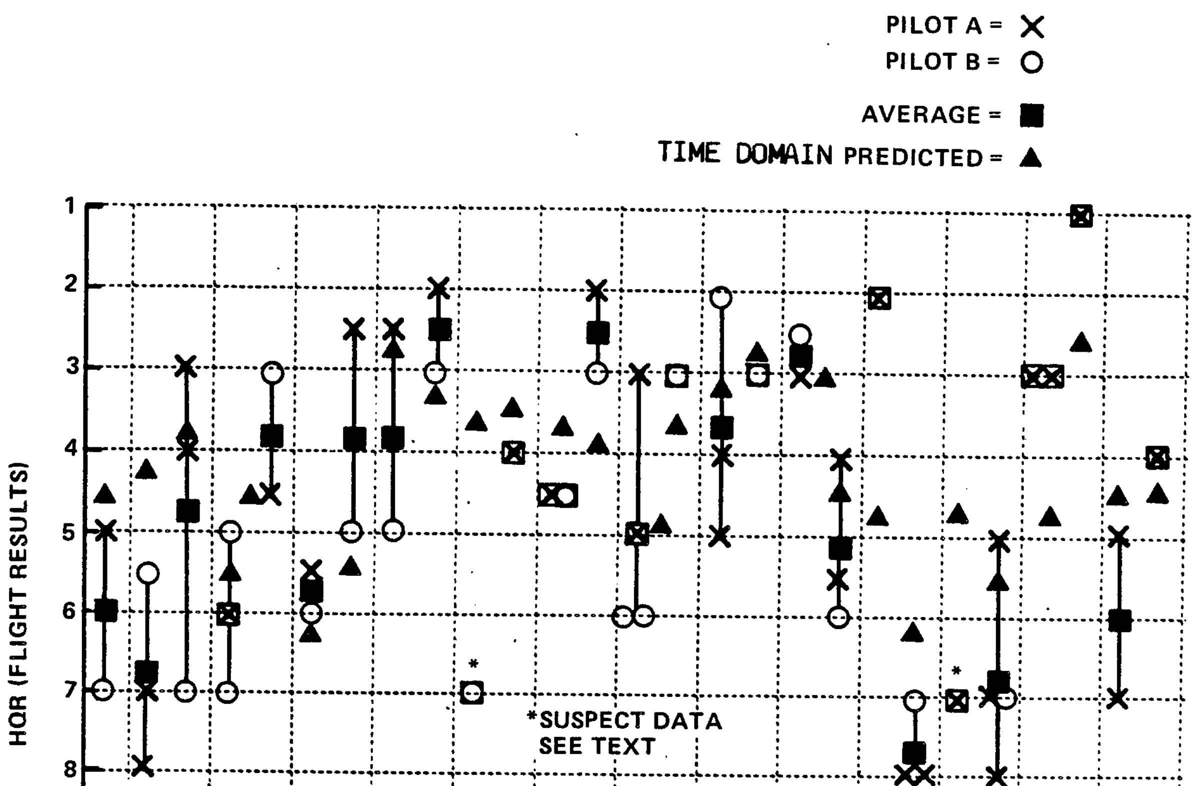


Figure 12 PIO TENDENCY CLASSIFICATION



ω_n	$1/\tau_{\theta_2}$	CONFIG	
2.8	0.38	1-1-1	
2.8	0.72	1-2-2	
2.7	1.0	1-3-7	
1.8	0.72	2-1-1	
1.8	0.72	2-2-2	
T = 0.4	0.38	3-1-3	NEUTRL STATIC
T = 0.4	0.72	3-2-4	NEUTRL STATIC
2.8	0.38	4-1-1	1-1-1 + L/L
2.8	0.72	4-2-2	1-2-2 + L/L
2.7	1.0	4-3-7 *	1-7-7 + L/L
2.7	1.0	4-3-7-1	4-3-7 + W.0
1.8	0.38	5-1-1	2-1-1 + L/L
1.8	0.72	5-2-2	2-2-2 + L/L
2.3	0.38	6-1-1	SUPER AVG.
2.3	0.72	6-1-1-1	6-1-1 + W.0
2.3	0.38	6-2-1	6-1-1 + L/L
2.3	0.38	6-2-1-1	6-2-1 + W.0
2.8	0.72	7-1-4	CONV. A/C
1.5	0.4	8-1-5	CAL SHUTTLE
1.5	0.4	8-1-5-1	8-1-5 + W.0
1.1	0.4	8-2-5	MOD. SHUTTLE
1.1	0.4	8-2-5-1 *	8-1-5 + W.0
1.5	0.4	8-3-5	OFT
1.5	0.4	8-3-5-1	8-3-5 + W.0
1.5	0.4	8-4-6	CANARD
1.5	0.4	8-5-5	8-1-5 + T.D.
1.5	0.4	8-5-5-1	8-5-5 + W.0

Figure 13 PILOT RATINGS

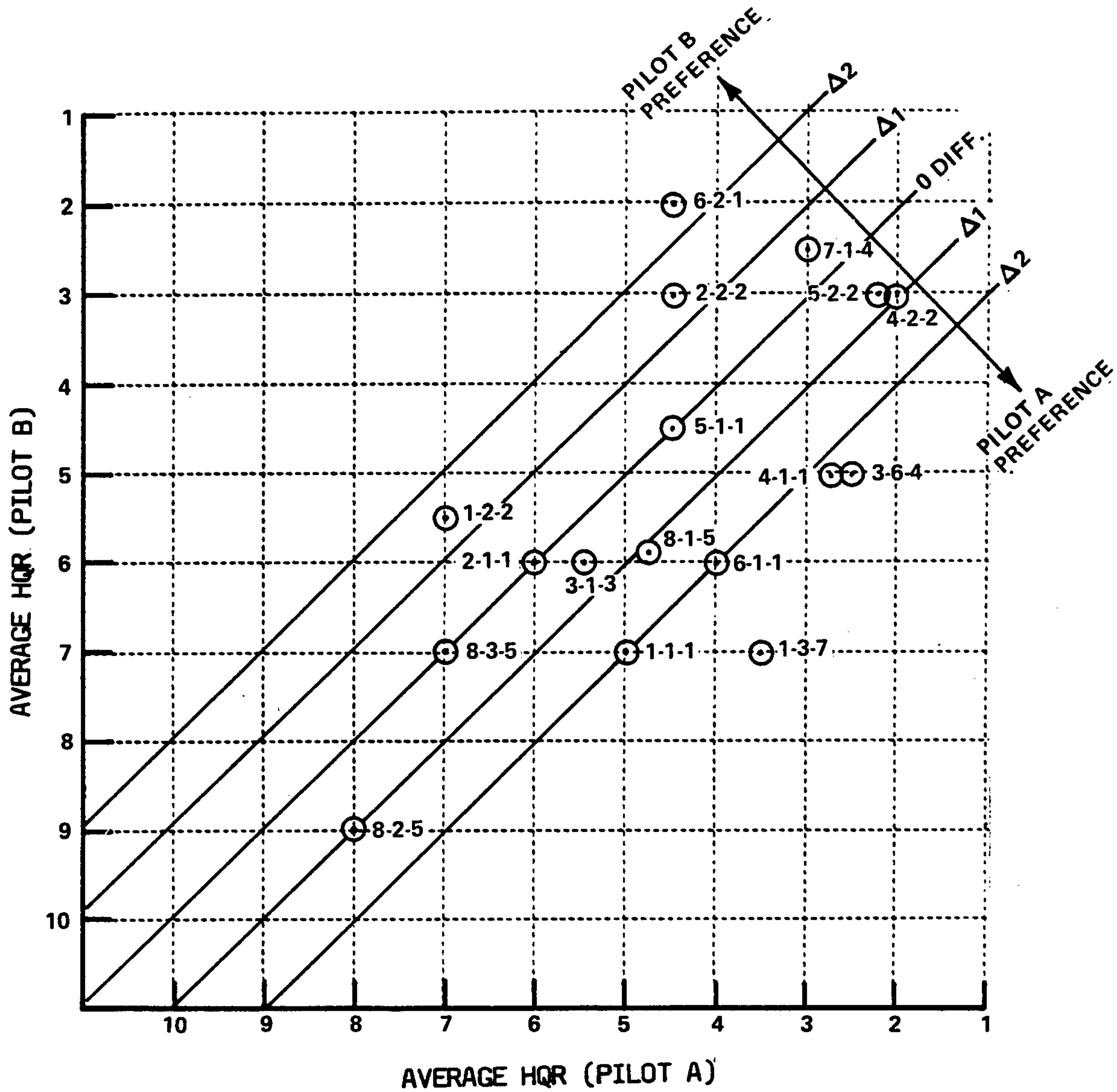


Figure 14 PILOT RATING DEVIATION

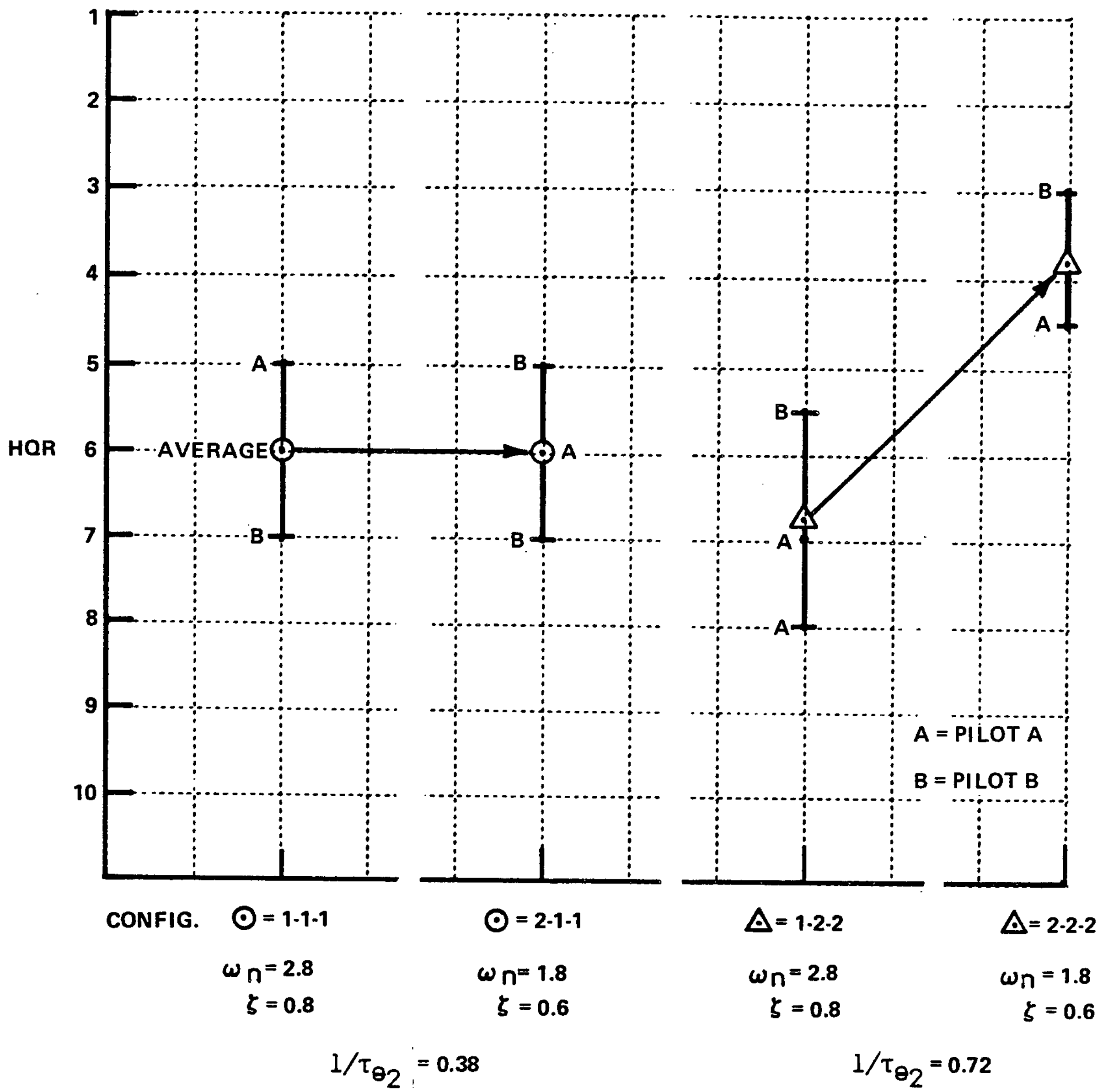


Figure 15 EFFECT OF VARYING ωn WITH "CONVENTIONAL" INTEGRAL - PROPORTIONAL PITCH RATE FEED BACK AT TWO VALUES OF $1/\tau_{\theta 2}$

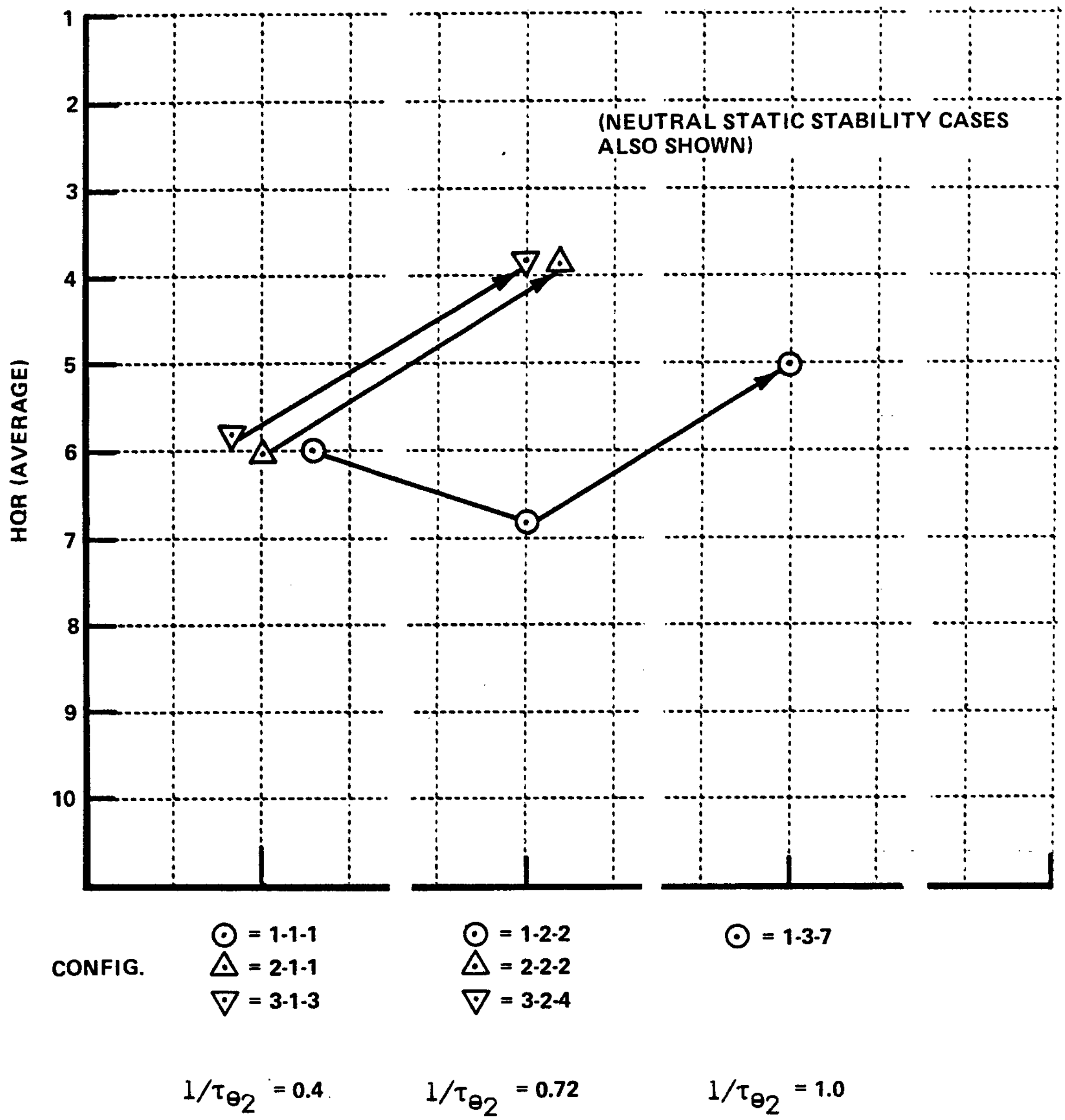


Figure 16 EFFECT OF VARYING $1/\tau_{\theta_2}$ WITH "CONVENTIONAL" INTEGRAL-PROPORTIONAL PITCH RATE FEED BACK (NO LEAD/LAG OR WASHOUT)

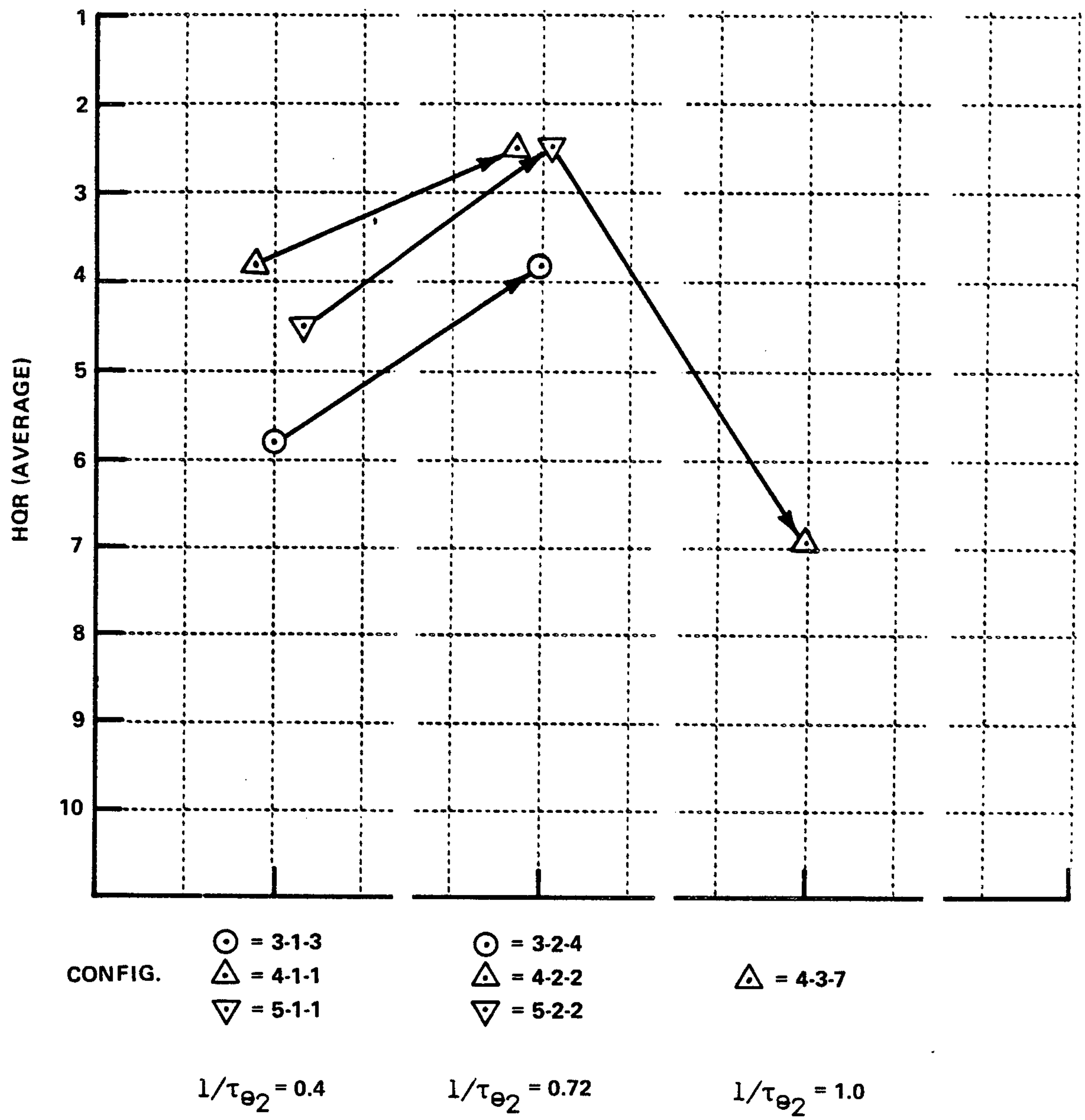
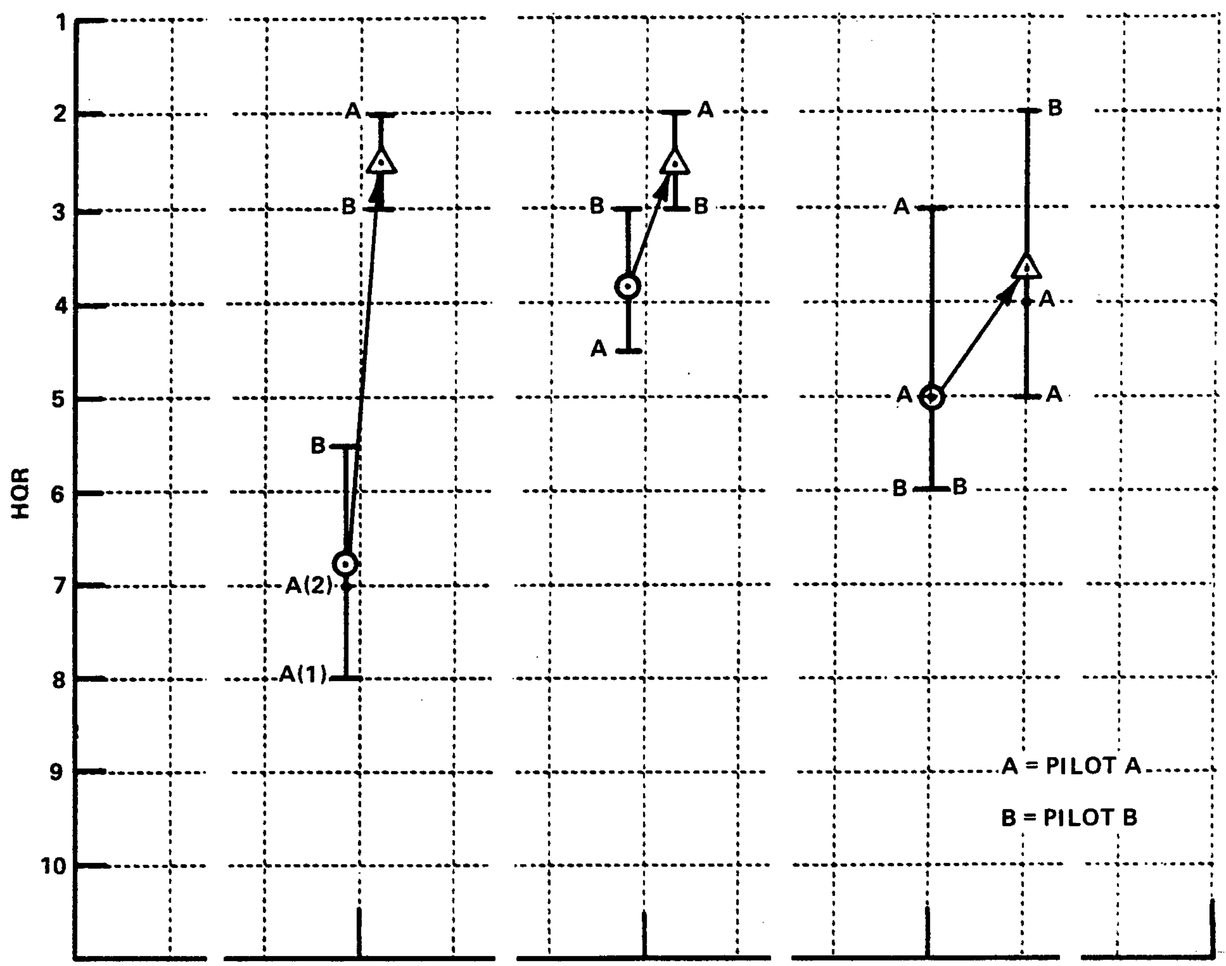


Figure 17 EFFECT OF VARYING $1/\tau_{\theta 2}$ WITH LEAD/LAG PRE-FILTER (INCLUDES NEUTRAL STATIC CASE)



CONFIG	⊙ = 1-2-2 △ = 4-2-2	⊙ = 2-2-2 △ = 5-2-2	⊙ = 6-1-1 △ = 6-2-1
ω_n	2.8	1.8	2.3
ζ	0.8	0.6	0.5
$1/\tau_{\theta_2}$	0.72	0.72	0.38

Figure 18 EFFECT OF LEAD/LAG PRE-FILTER AT THREE VALUES OF ω_n AND $1/\tau_{\theta_2}$ (INCLUDING SUPER AUGMENTED CASES)

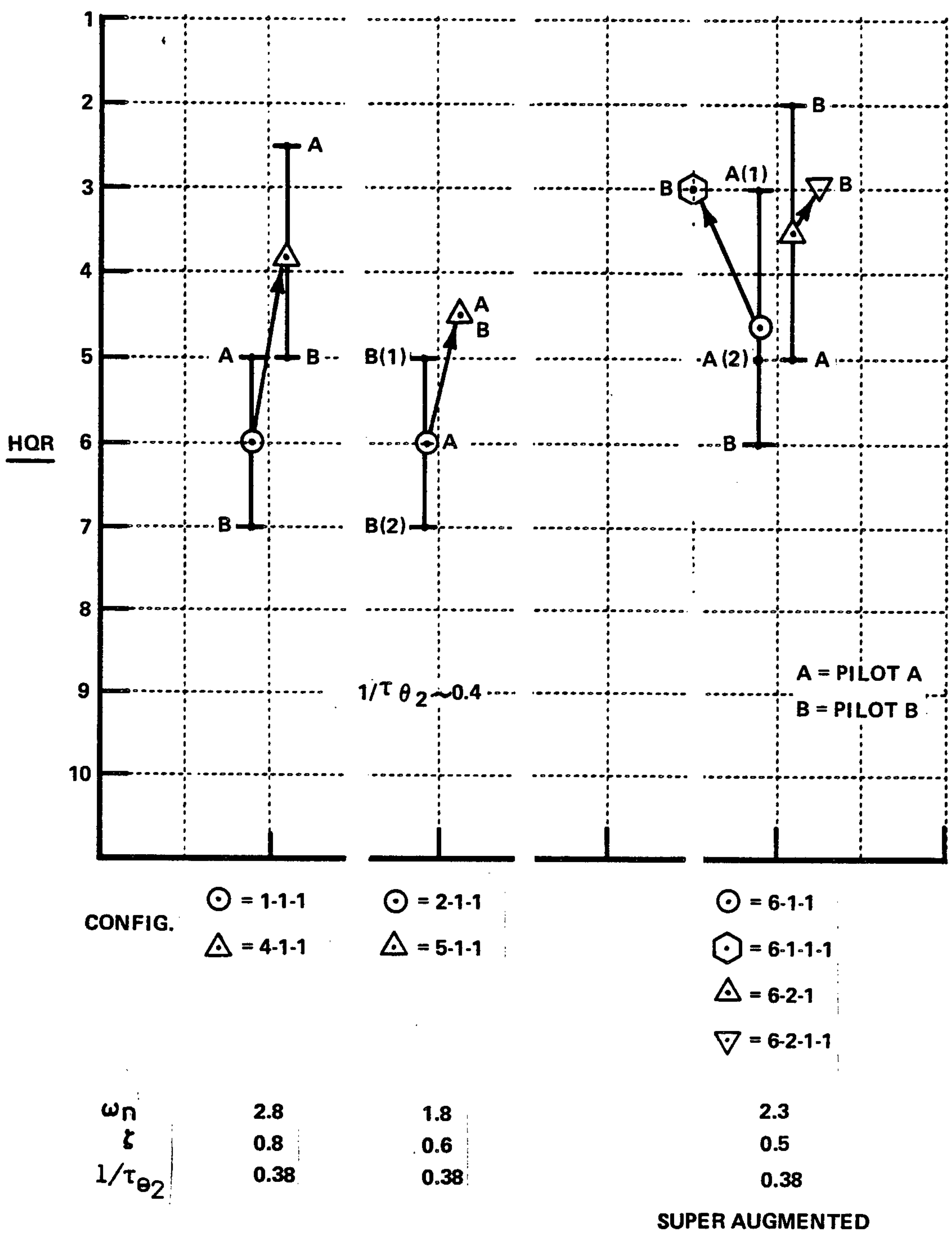


Figure 19 EFFECTS OF LEAD/LAG AND WASHOUT PREFILTERS AT $1/\tau_{\theta_2} \sim 0.4$ (NON SHUTTLE LIKE CONFIGURATIONS)

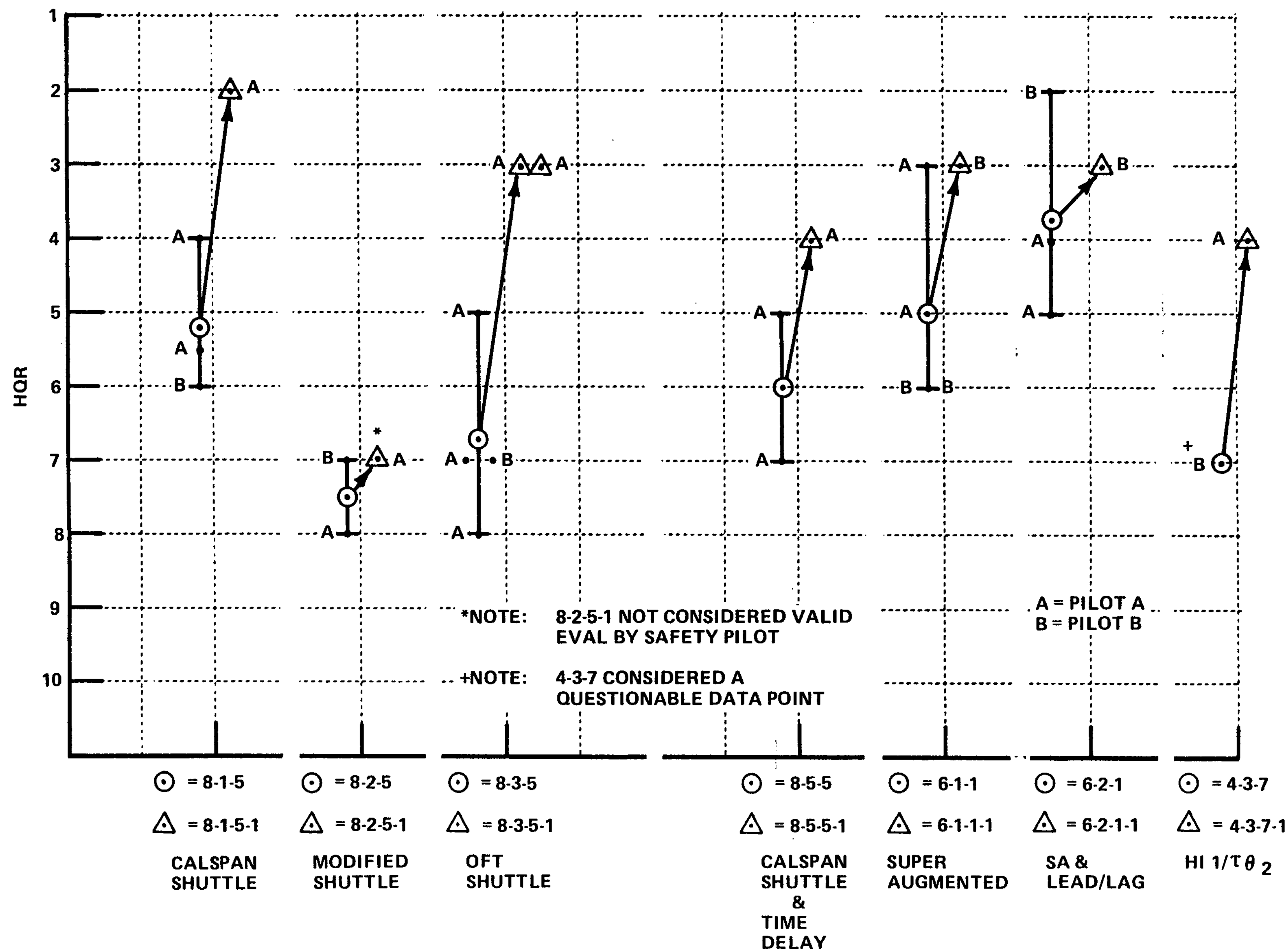


Figure 20 EFFECT OF WASHOUT PRE-FILTER

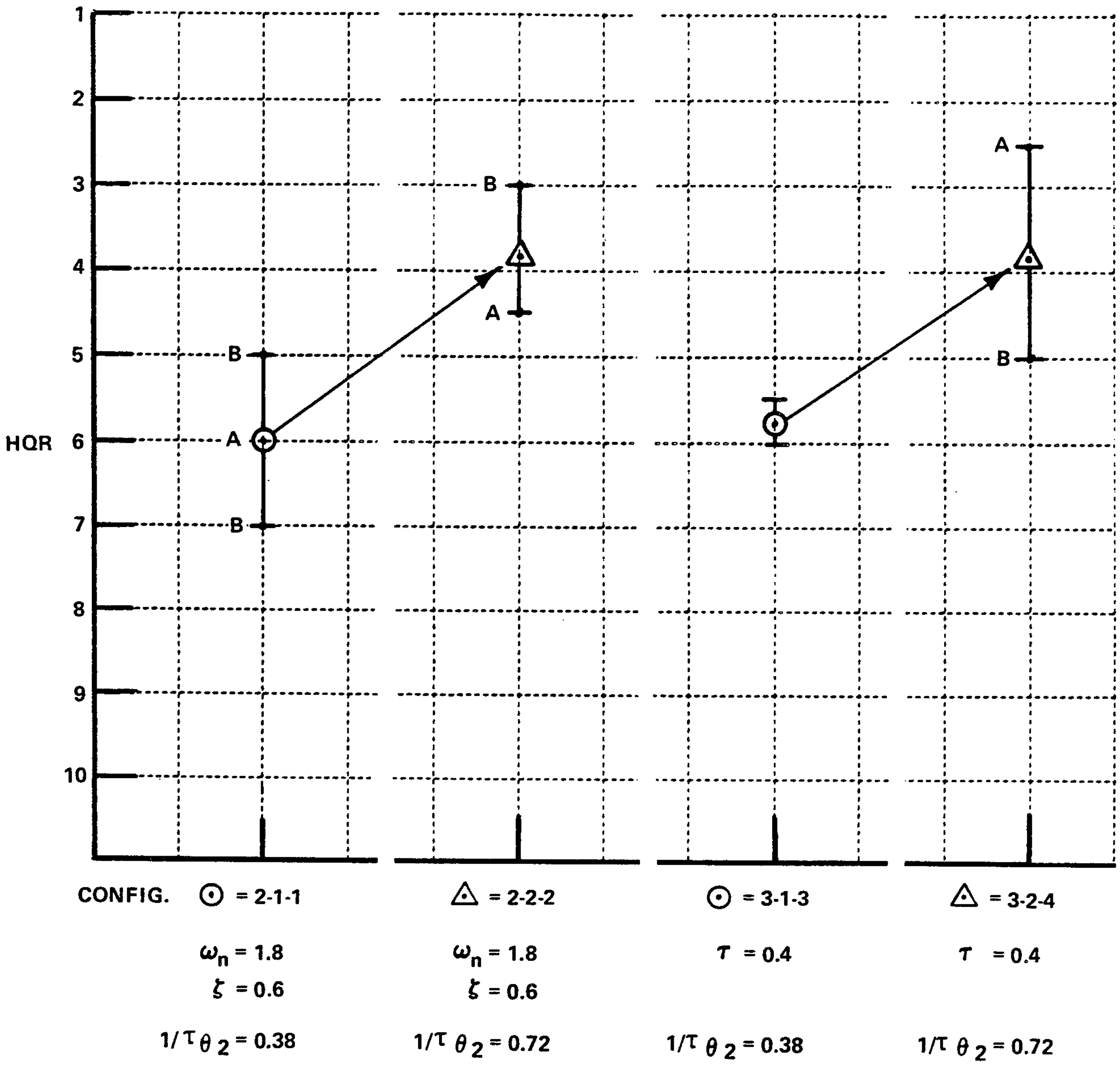
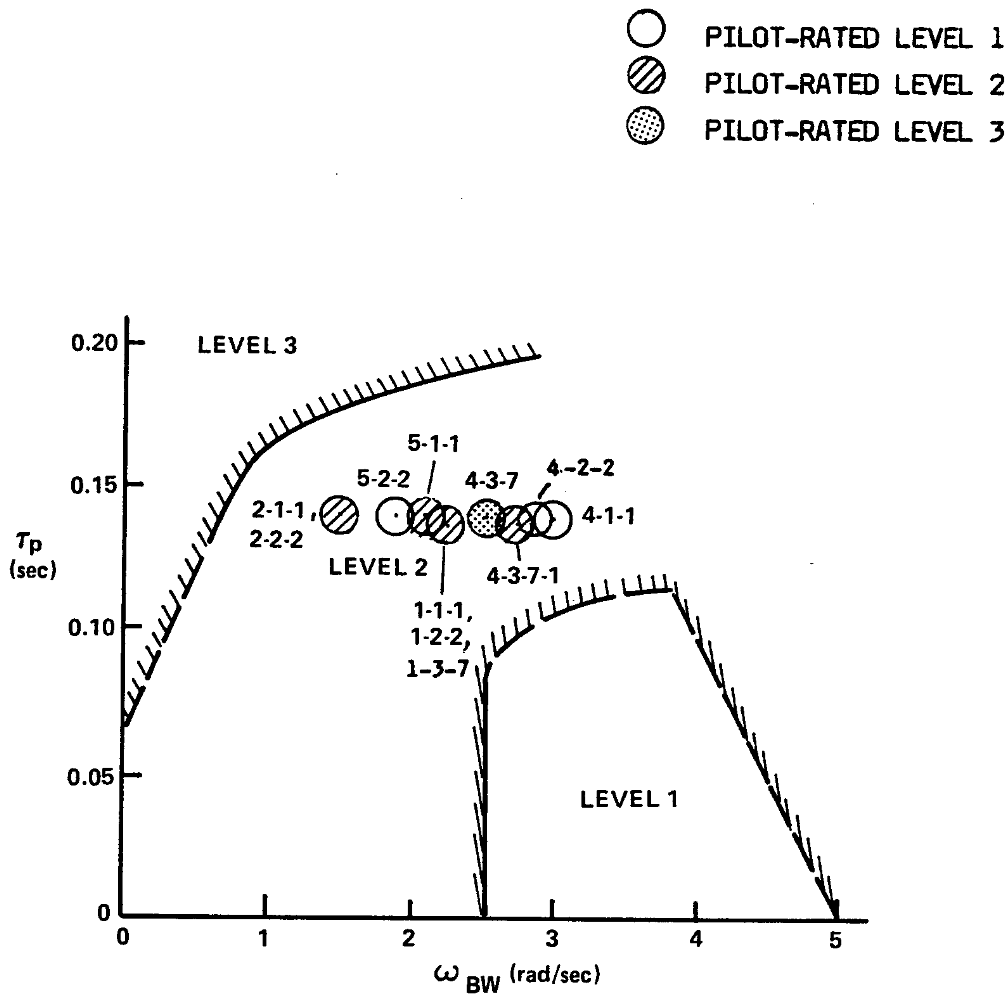


Figure 21 EFFECTS OF NEUTRAL STATIC STABILITY WITH CHANGES IN $1/\tau_{\theta_2}$



CATEGORY C FLIGHT PHASE

Figure 22 BANDWIDTH CRITERION RESULTS CONFIGURATIONS 1, 2, 4, 5

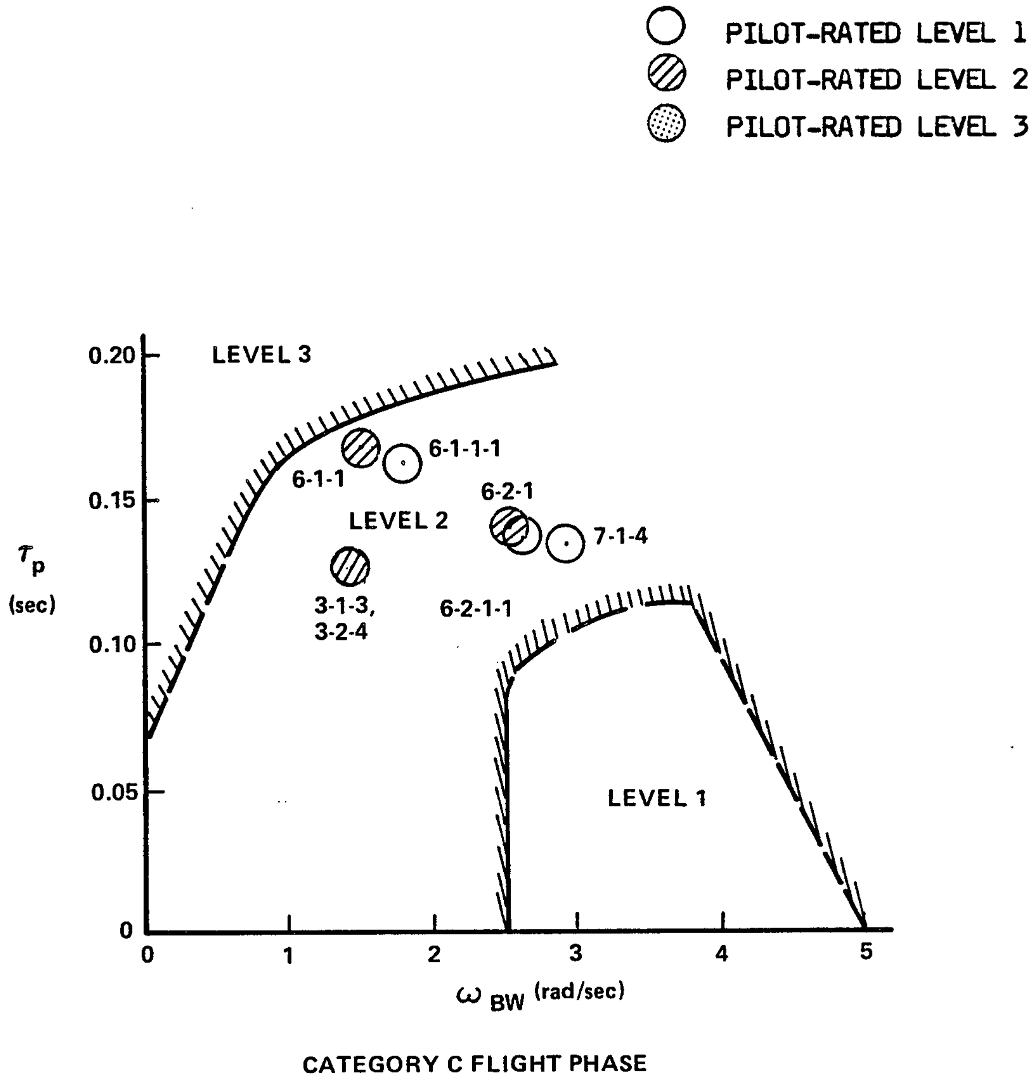


Figure 23 BANDWIDTH CRITERION RESULTS CONFIGURATIONS 3, 6, 7

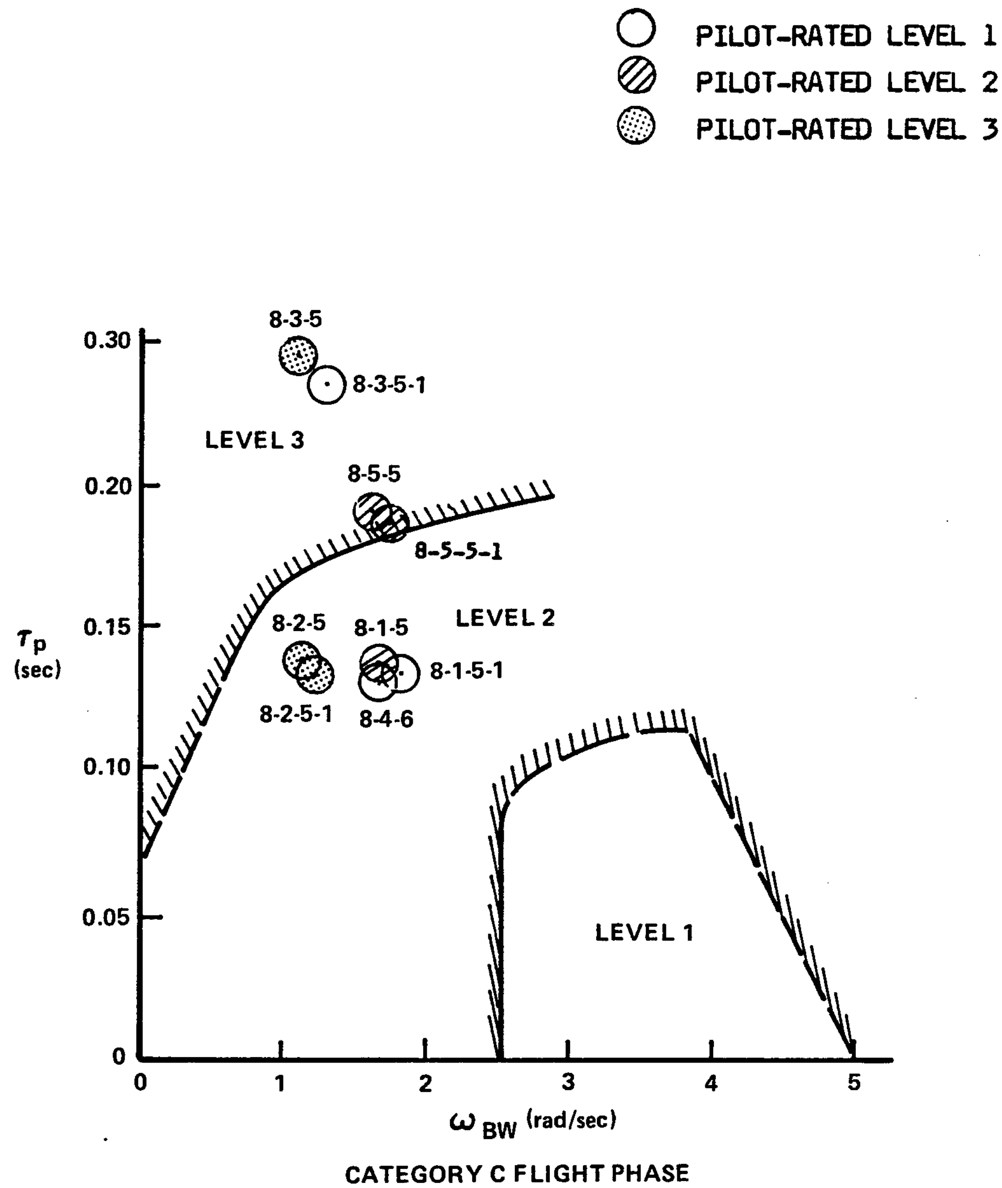


Figure 24 BANDWIDTH CRITERION RESULTS CONFIGURATION 8

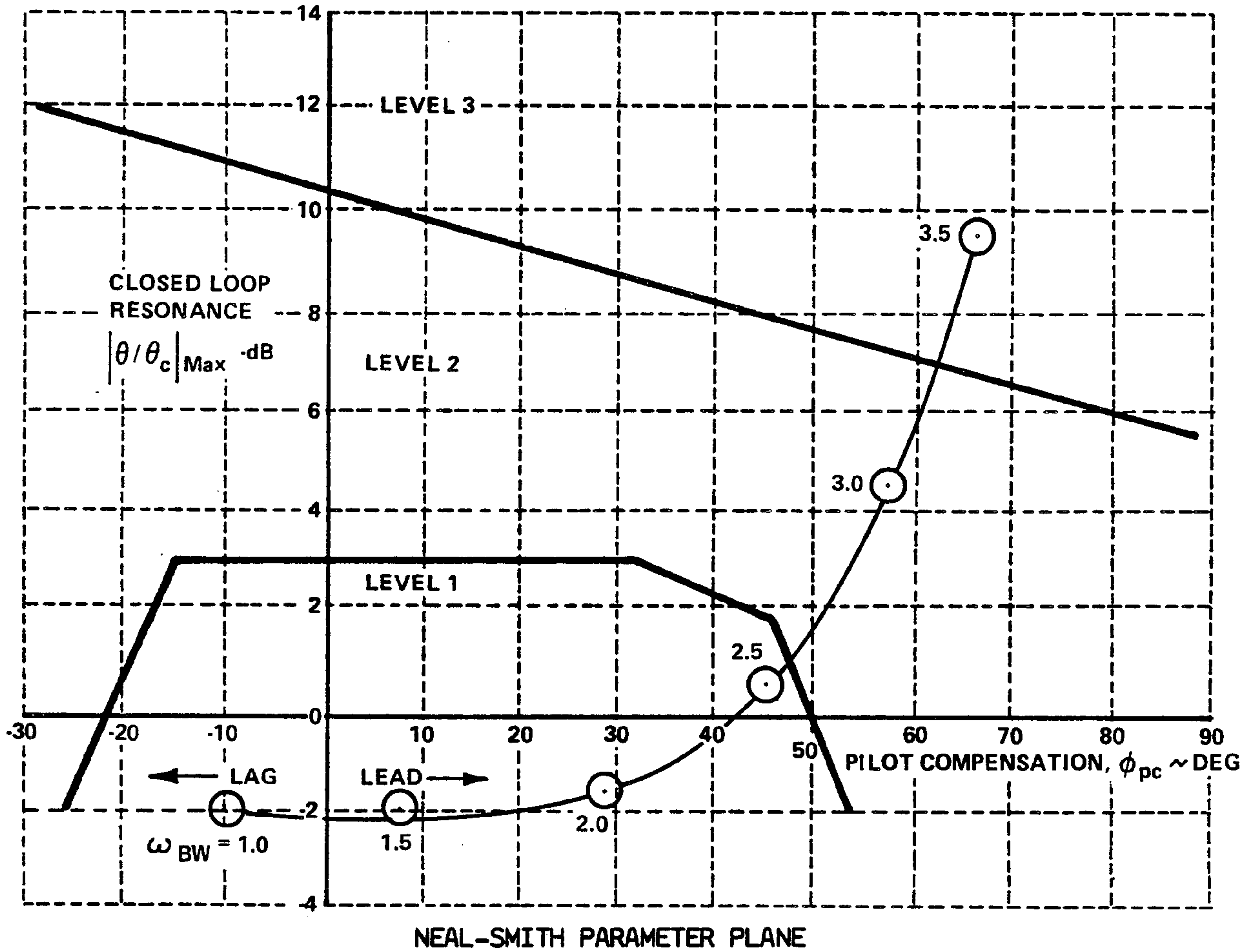


Figure 25 CONFIGURATION 1-1-1 (2 dB DROOP)

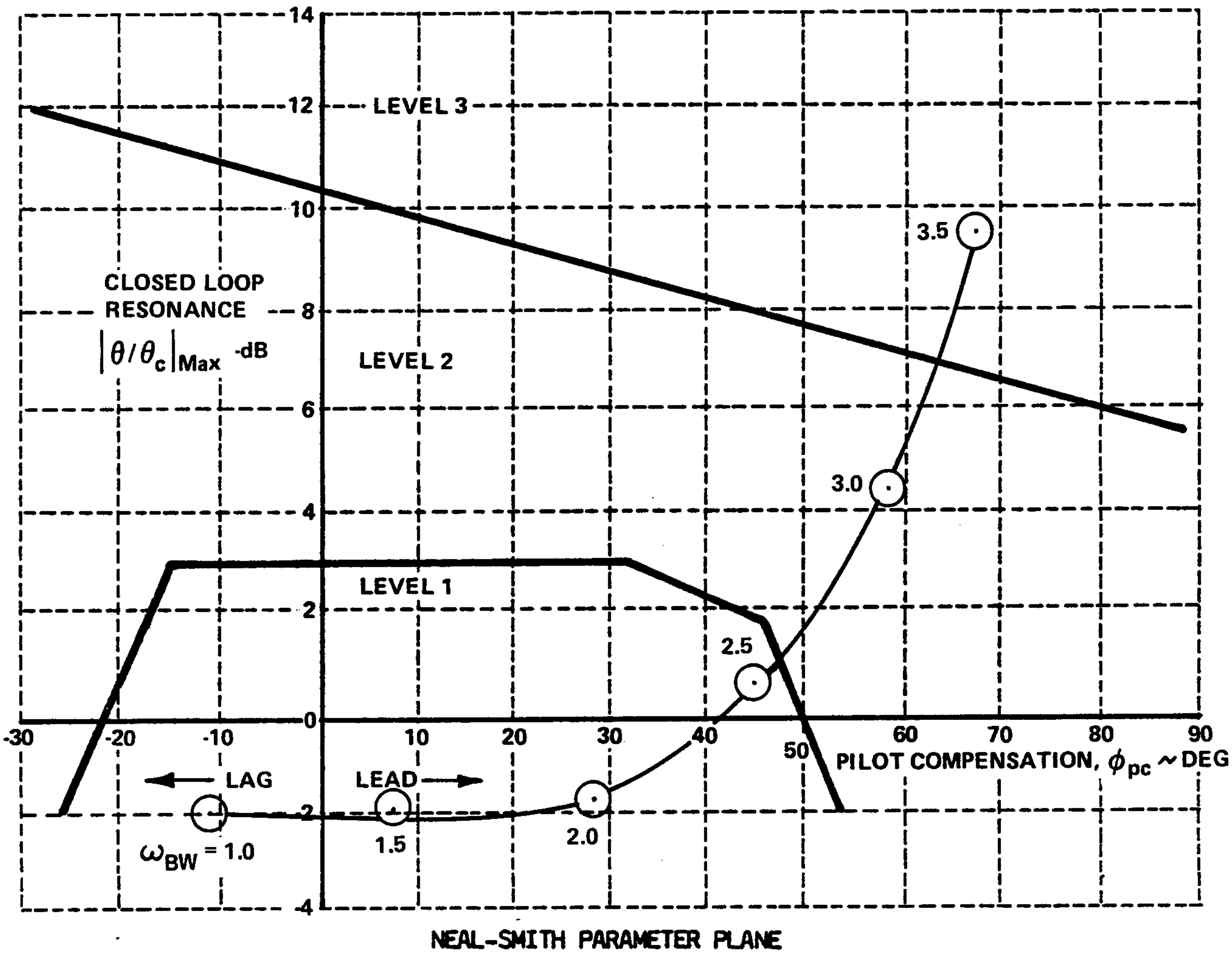
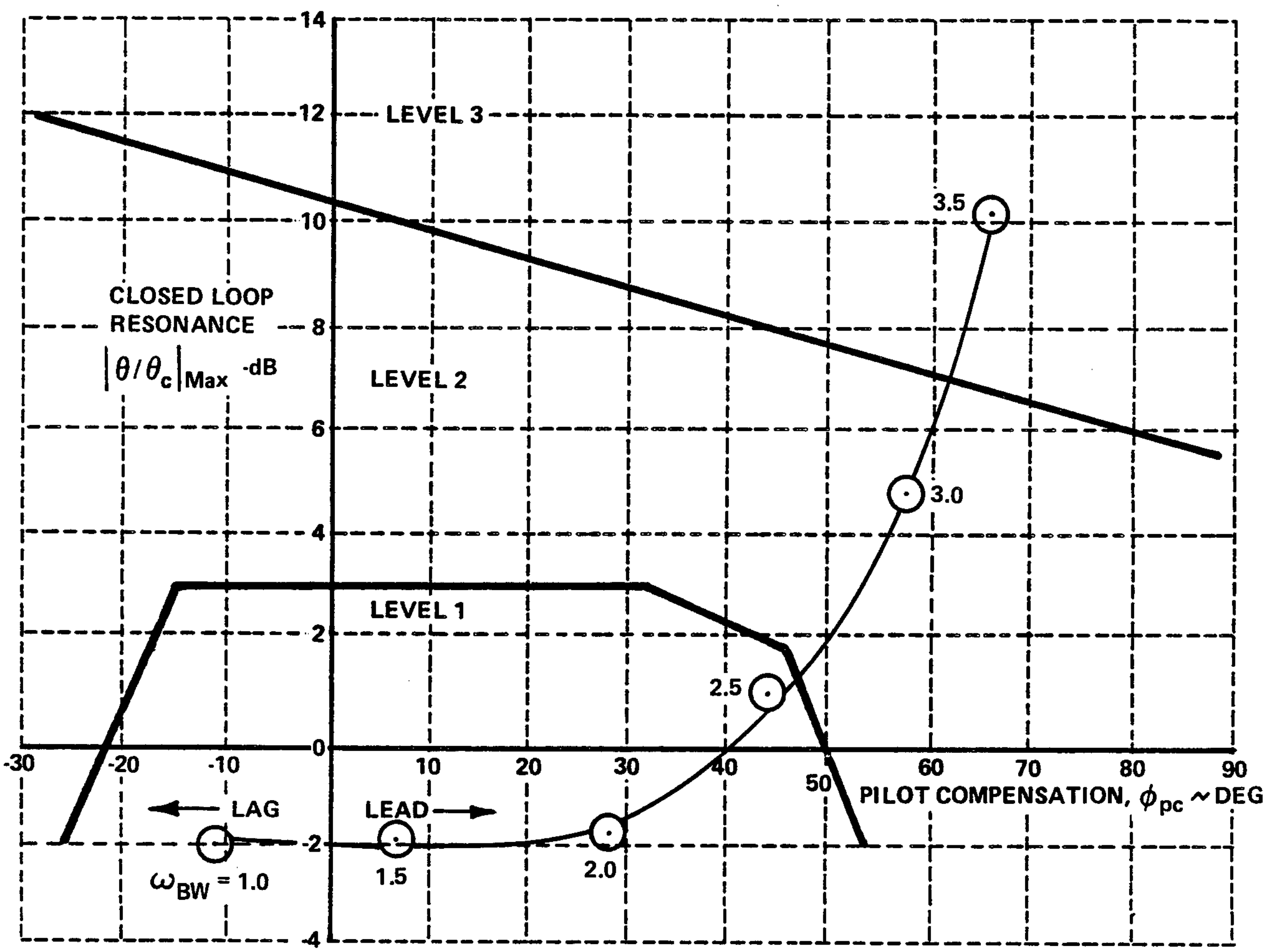


Figure 26 CONFIGURATION 1-2-2 (2 dB DROOP)



NEAL-SMITH PARAMETER PLANE

Figure 27 CONFIGURATION 1-3-7 (2 dB DROOP)

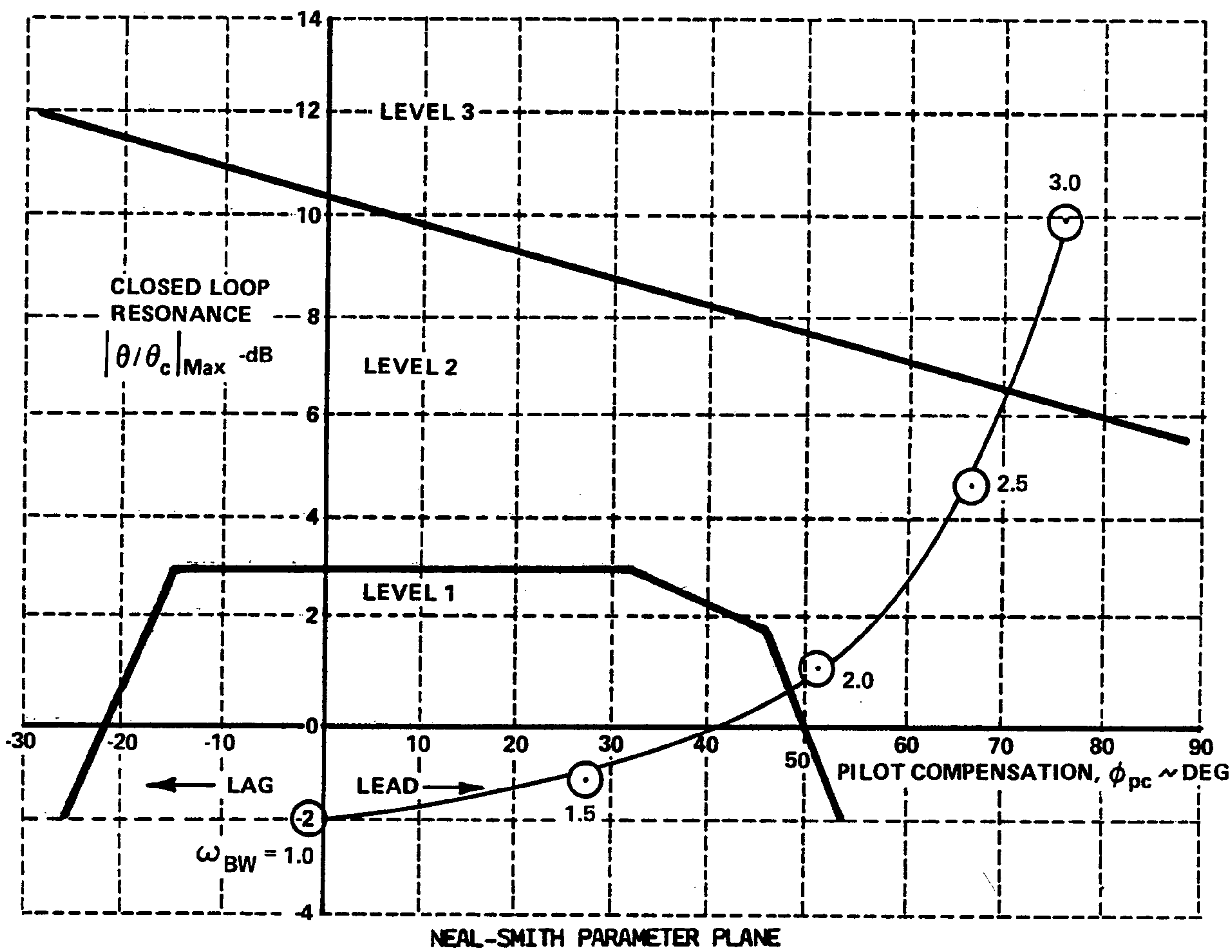


Figure 28 CONFIGURATION 2-1-1 (2 dB DROOP)

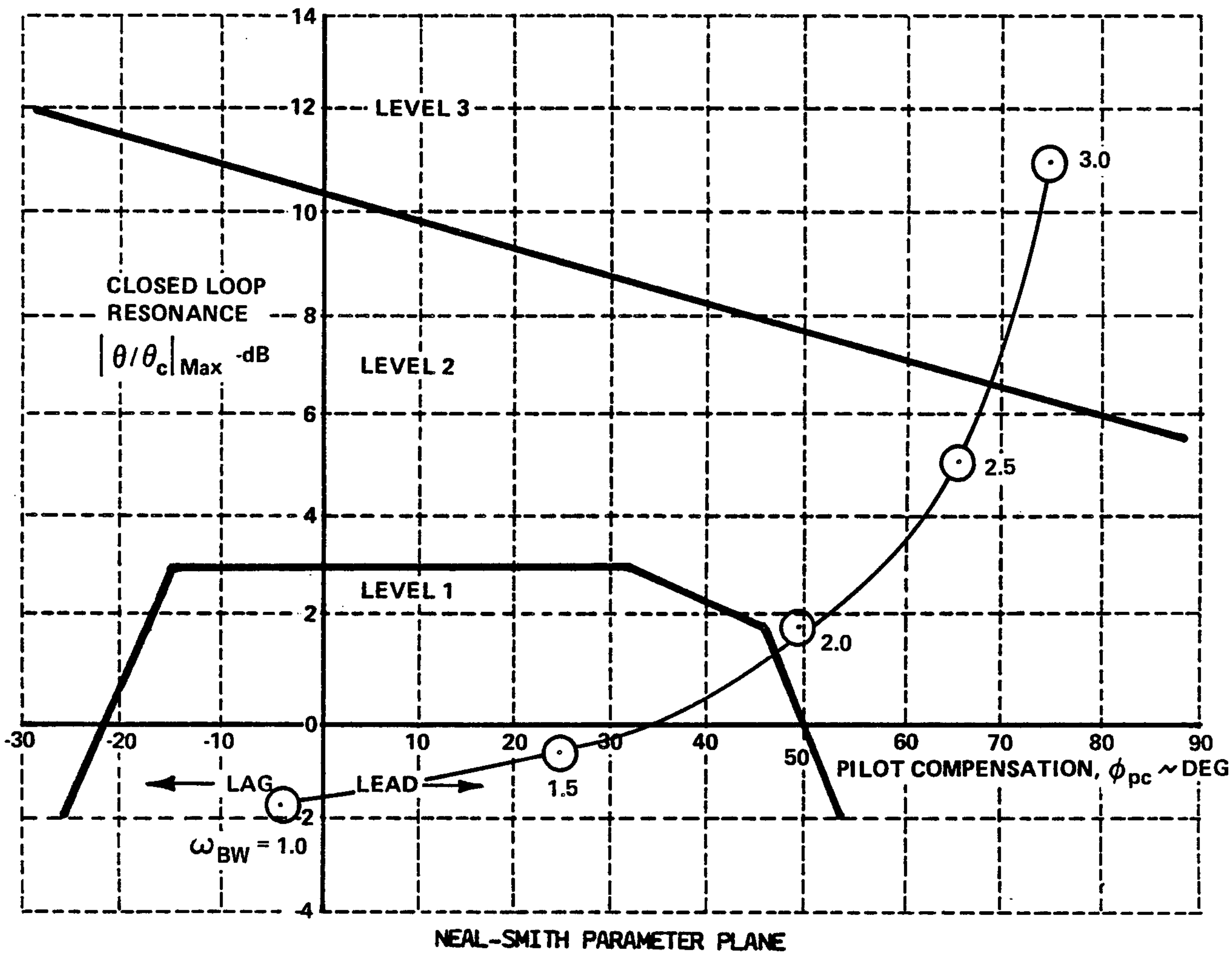


Figure 29 CONFIGURATION 2-2-2 (2 dB DROOP)

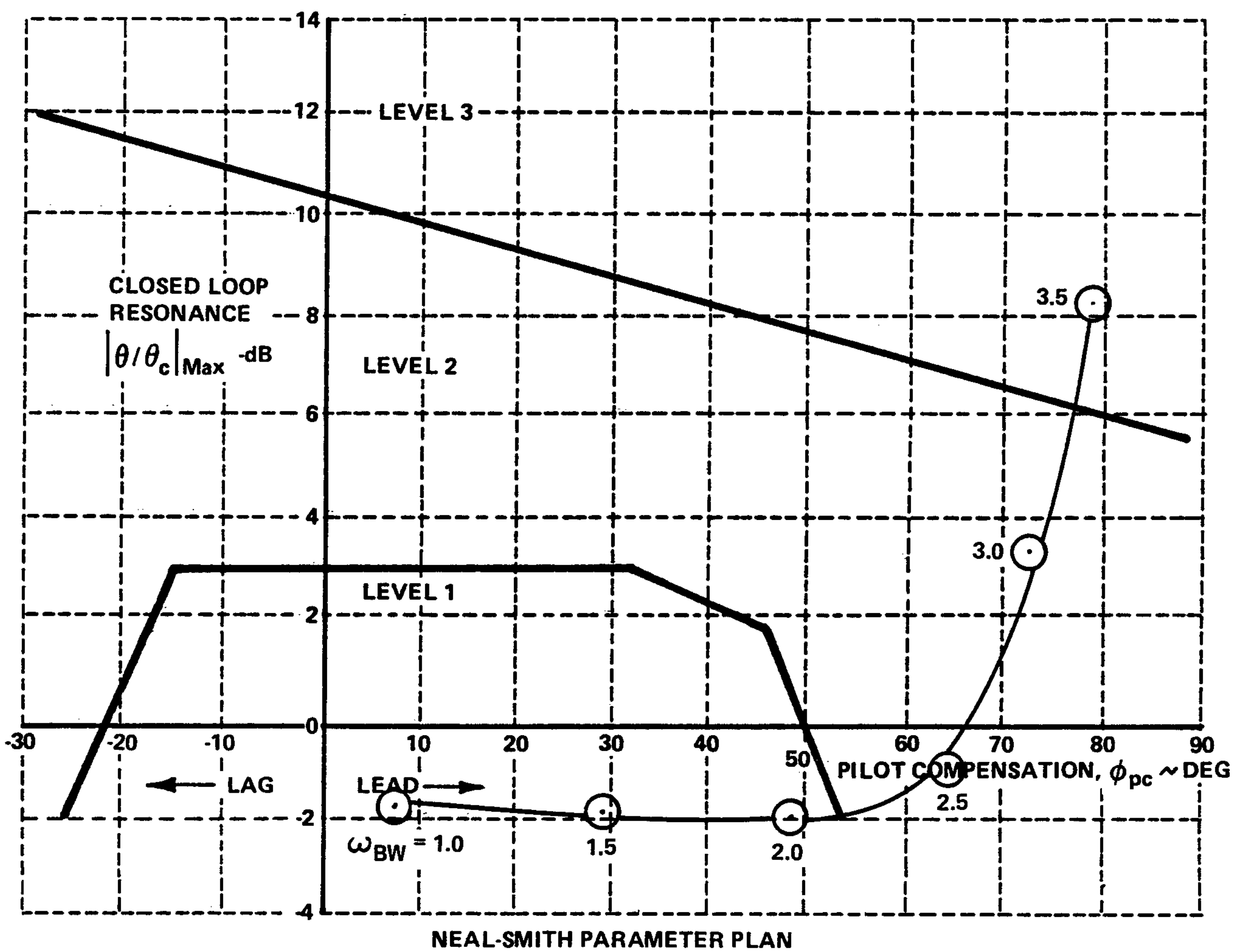


Figure 30 CONFIGURATION 3-1-3 (2 dB DROOP)

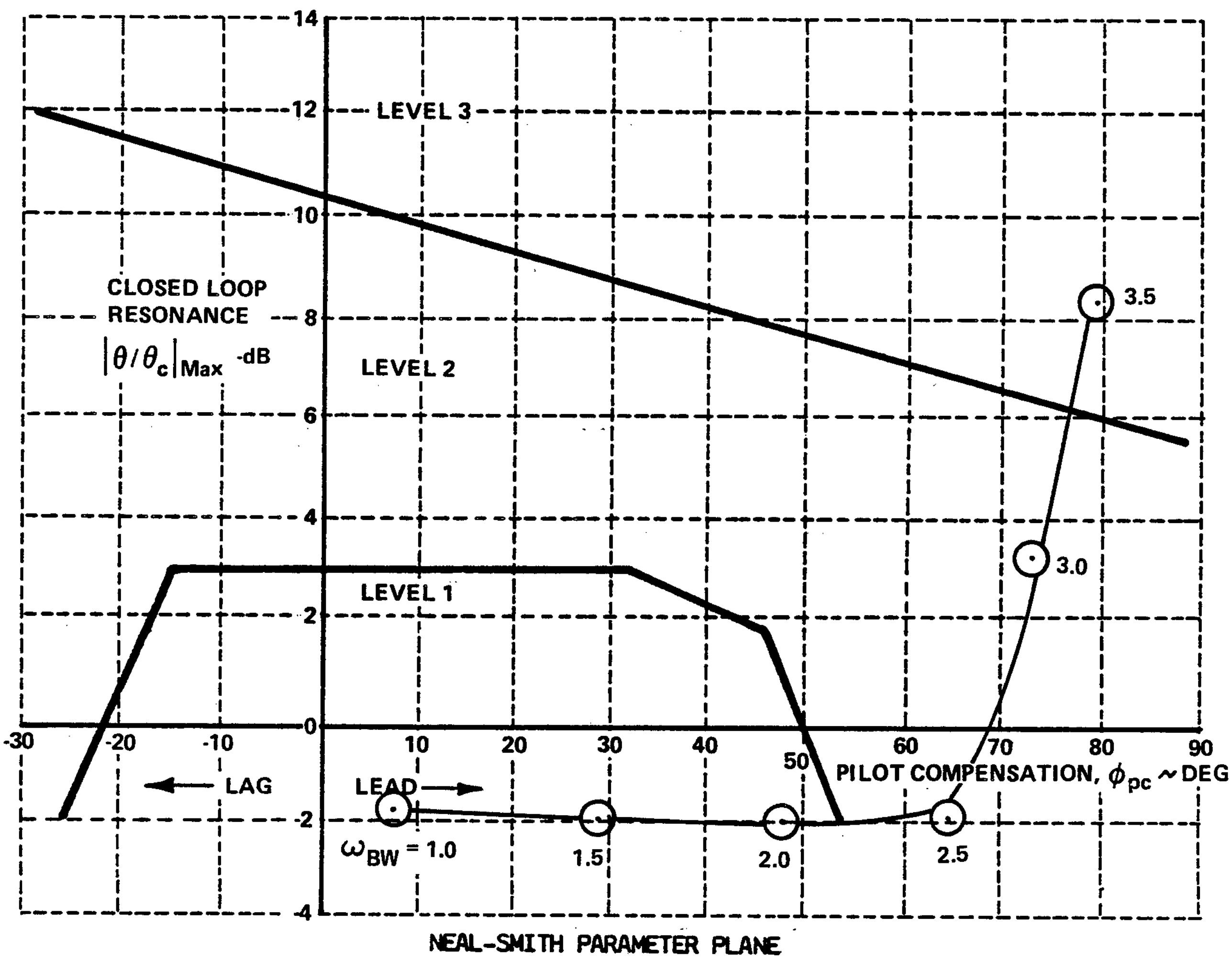
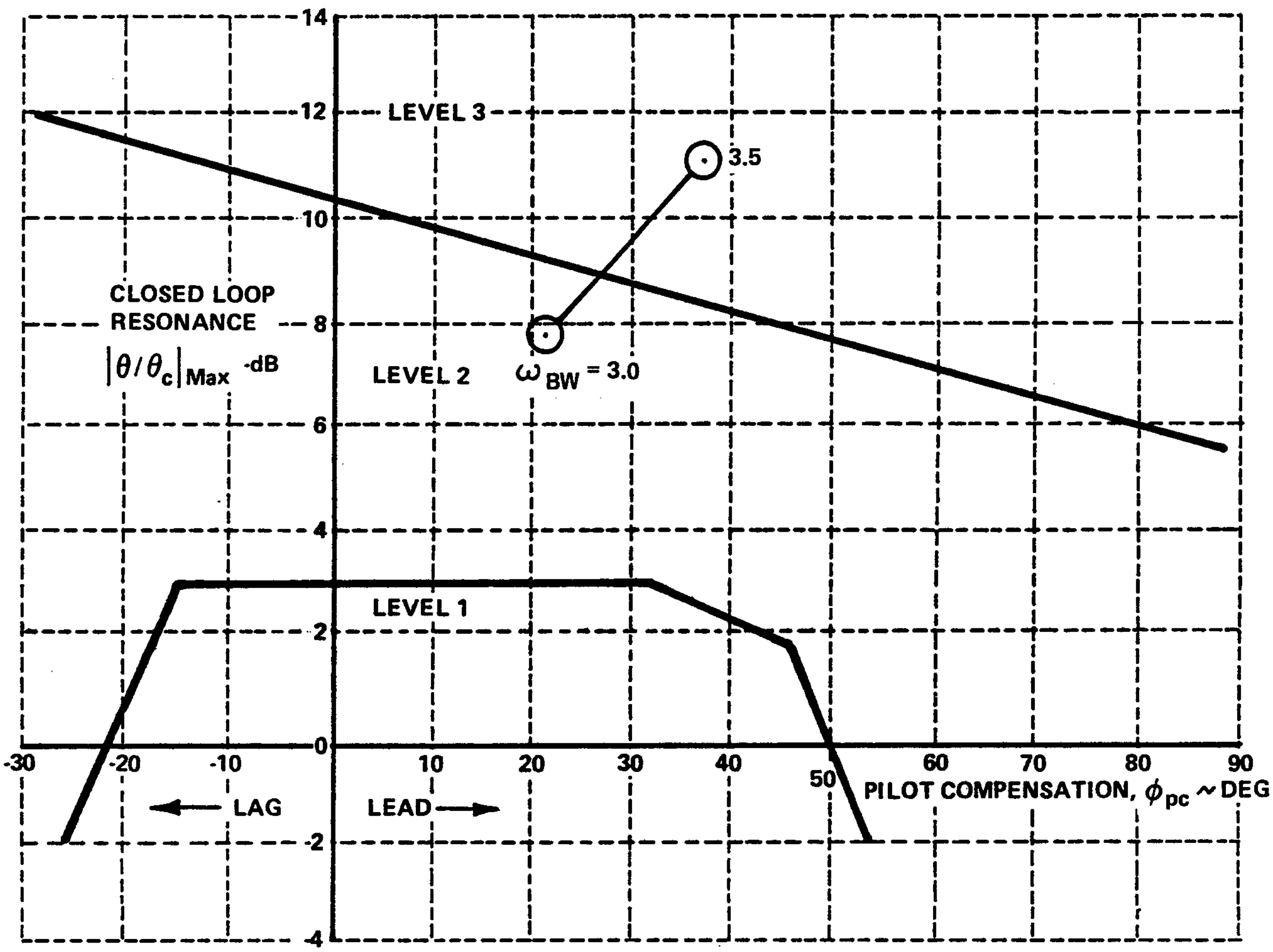


Figure 31 CONFIGURATION 3-2-4 (2 dB DROOP)



NEAL-SMITH PARAMETER PLANE

– REMAINING BANDWIDTH FREQUENCIES DID NOT YIELD SATISFACTORY SOLUTIONS

Figure 32 CONFIGURATION 4-1-1 (3 dB DROOP)

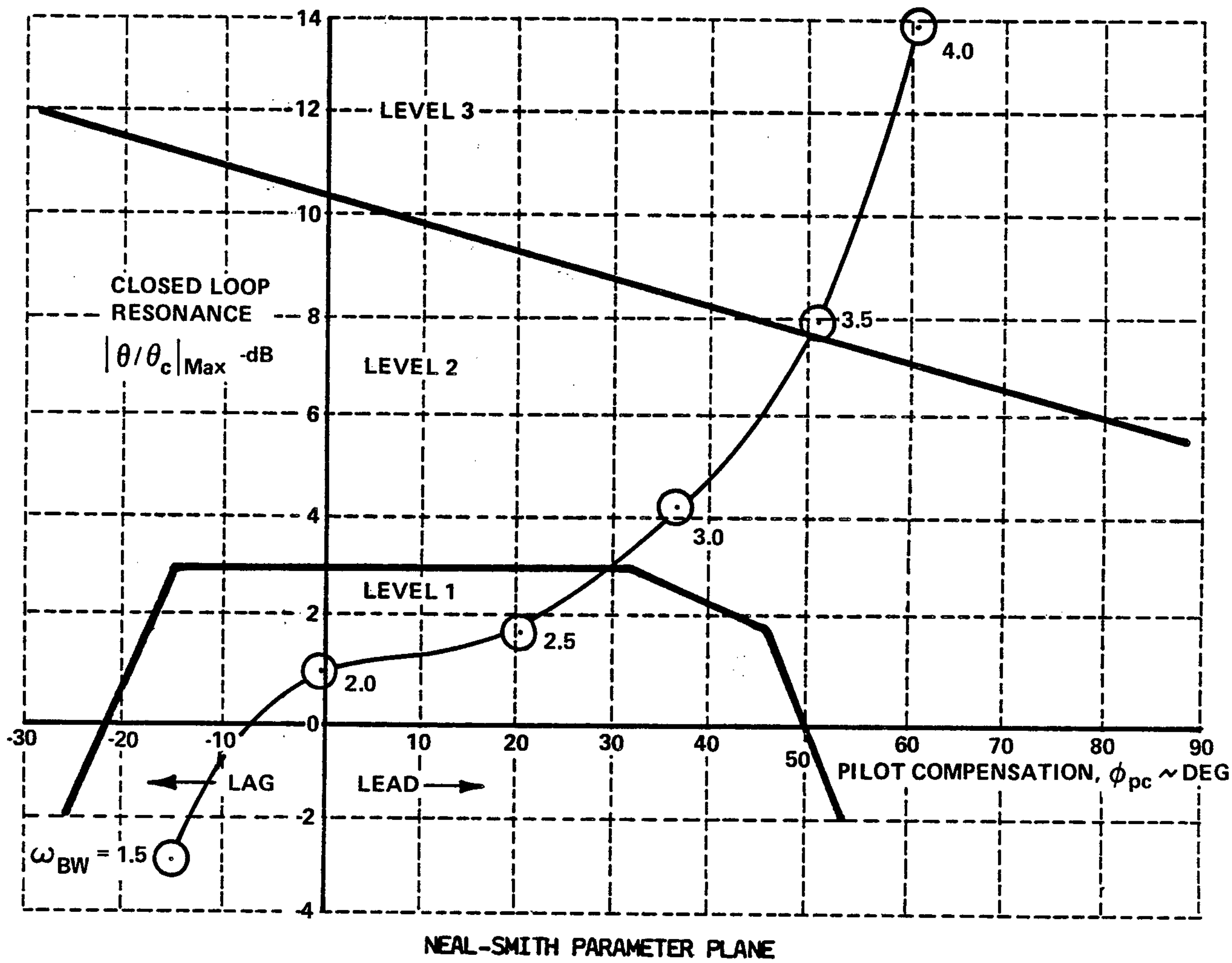


Figure 33 CONFIGURATION 4-2-2 (3 dB DROOP)

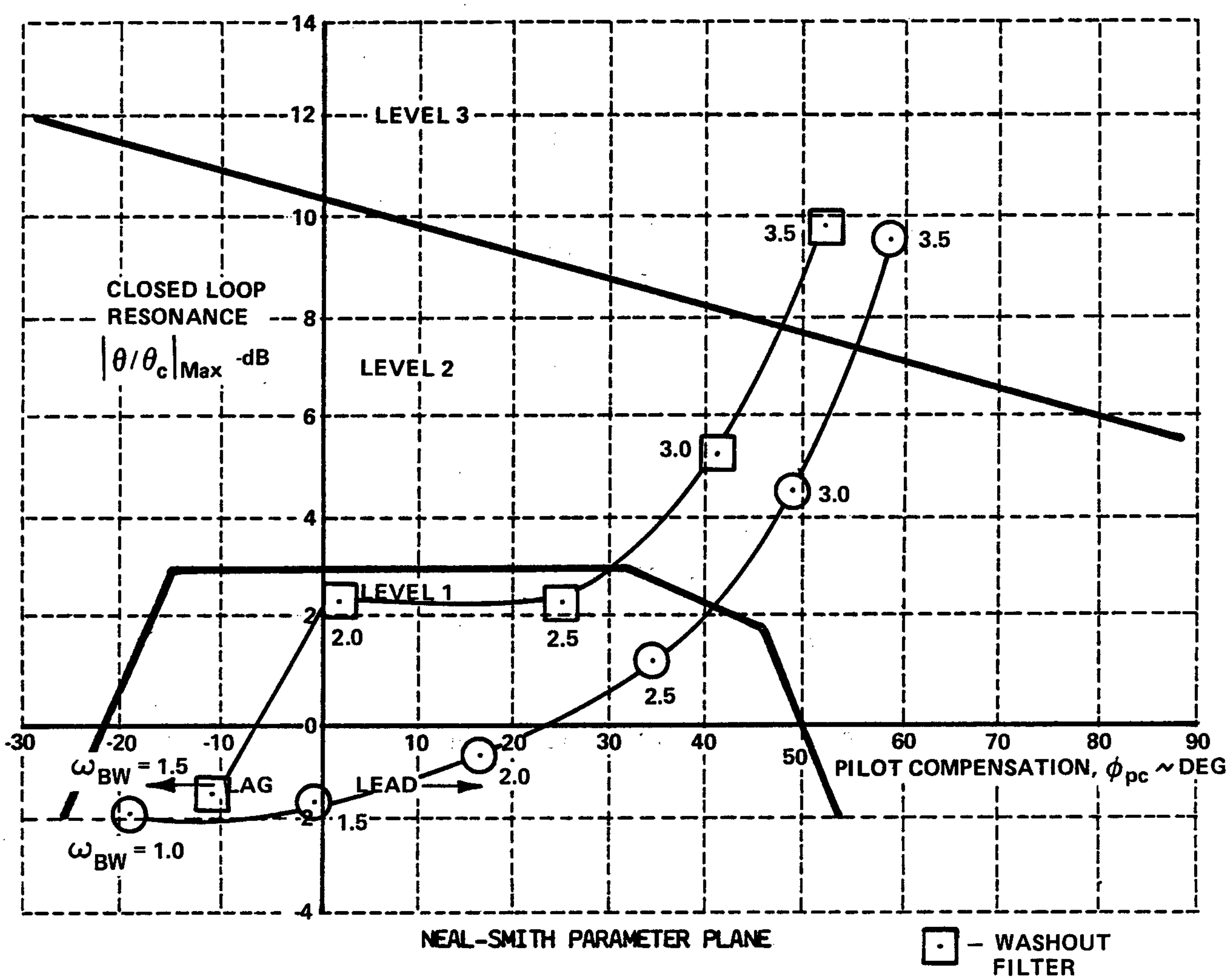
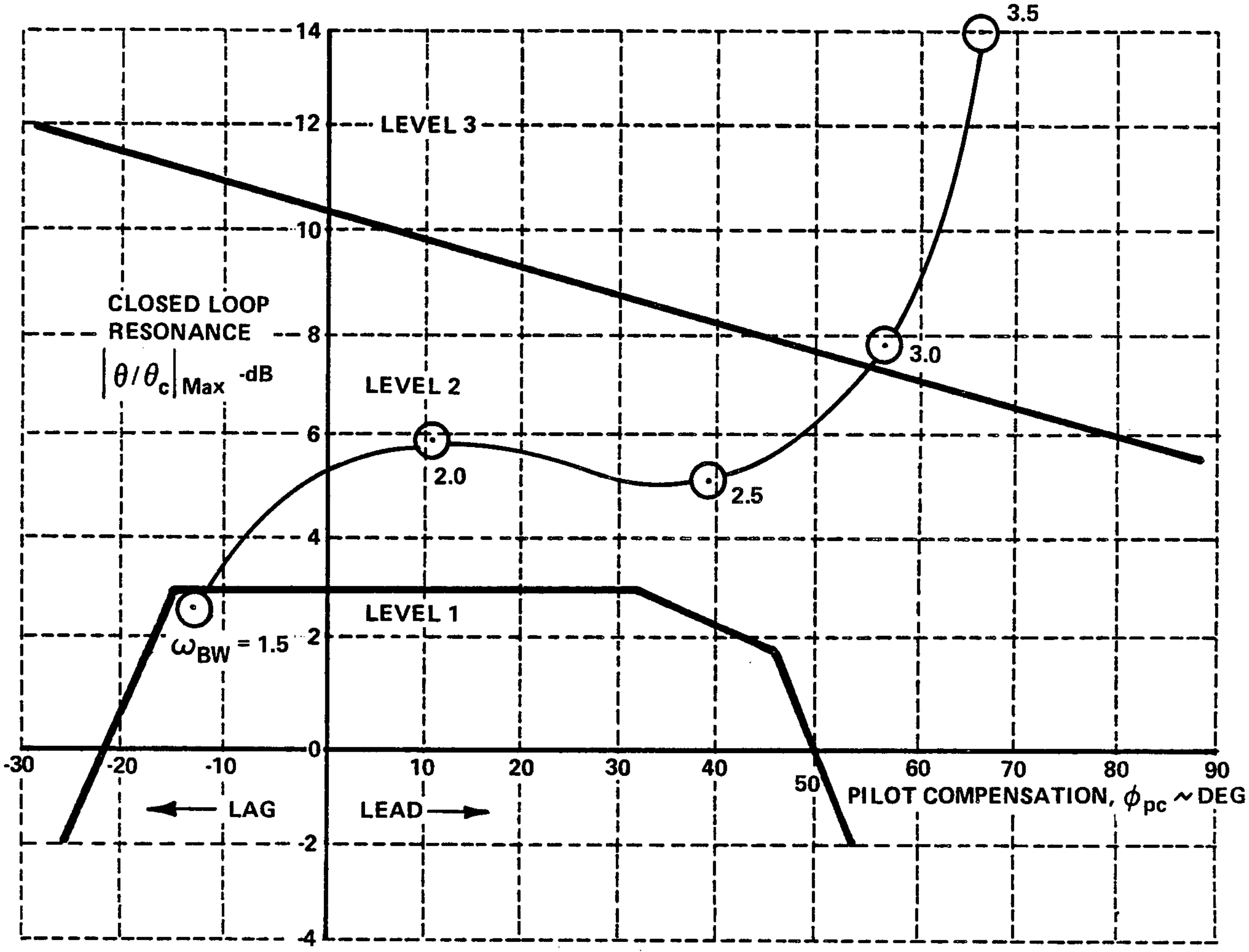


Figure 34 CONFIGURATION 4-3-7 (2 dB DROOP)



NEAL-SMITH PARAMETER PLANE

Figure 35 CONFIGURATION 5-1-1 (3 dB DROOP)

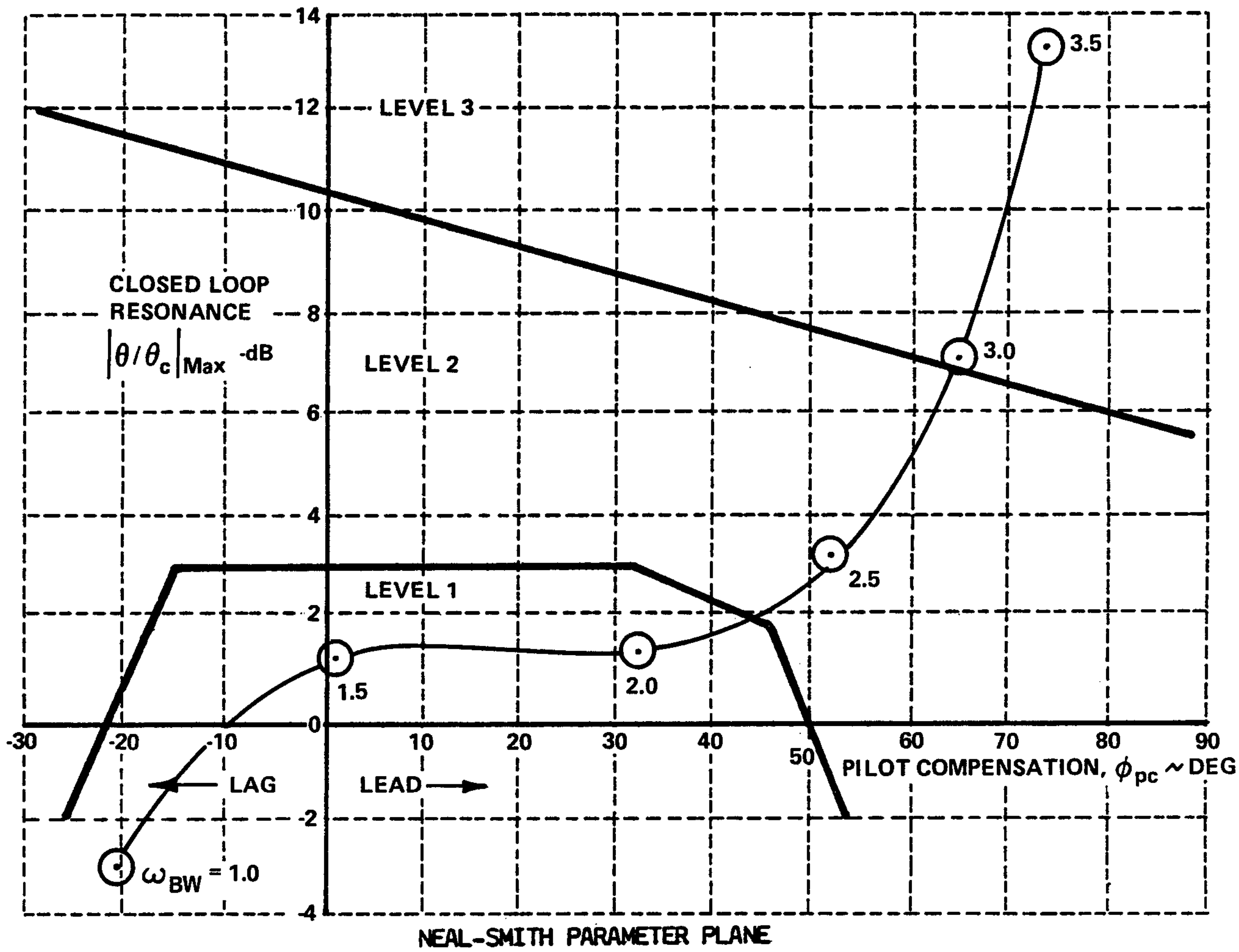


Figure 36 CONFIGURATION 5-2-2 (3 dB DROOP)

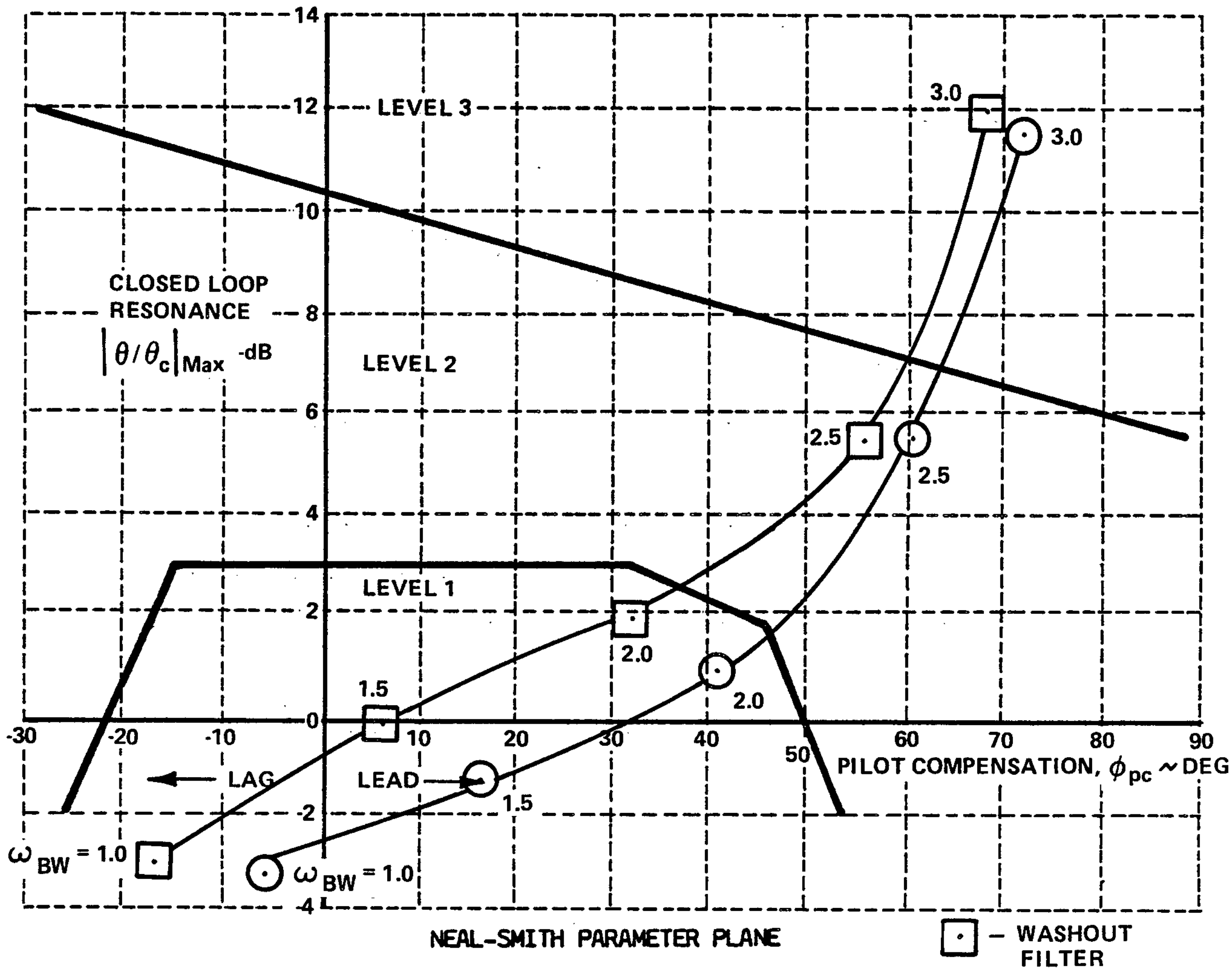


Figure 37 CONFIGURATION 6-1-1 (3 dB DROOP)

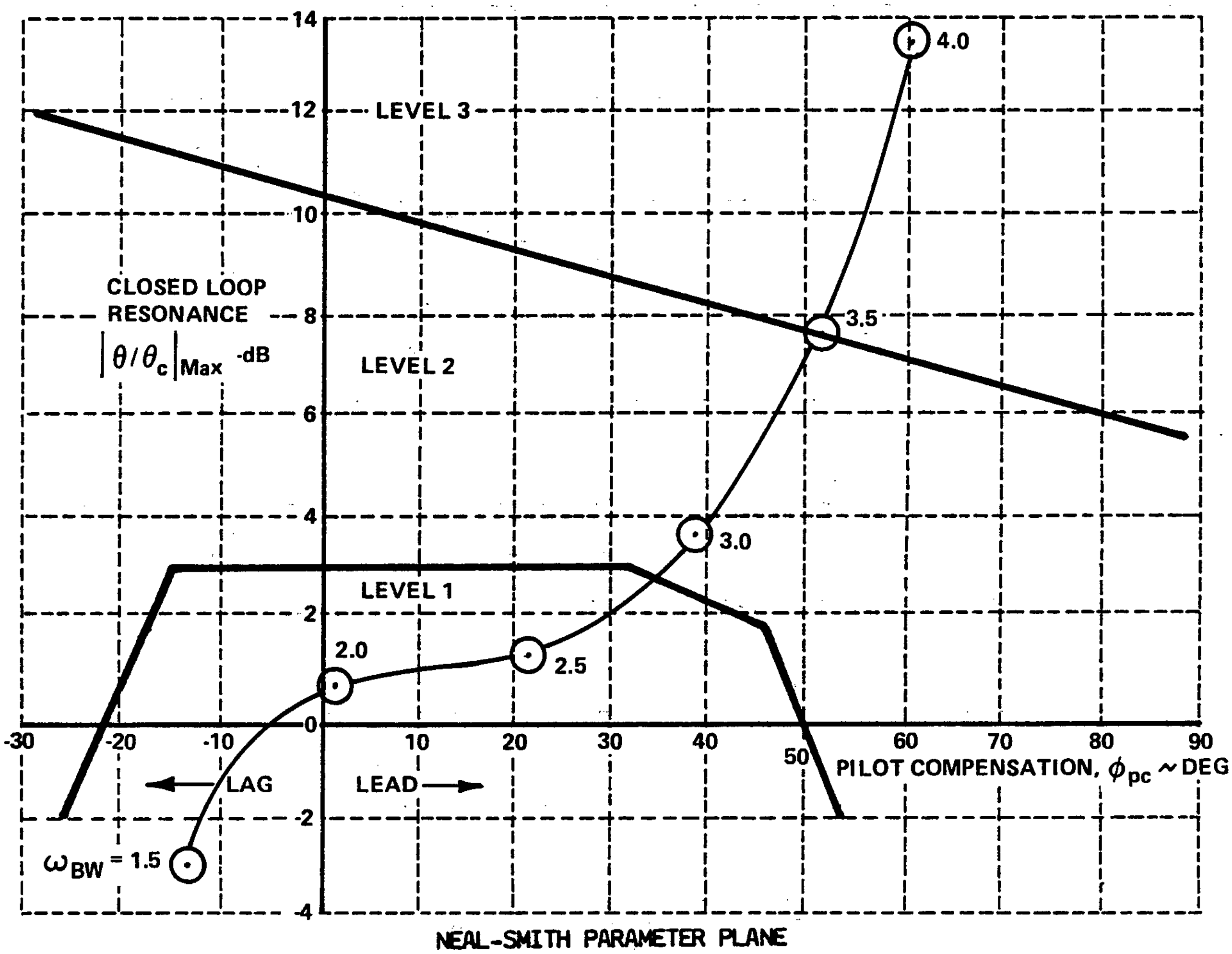


Figure 38 CONFIGURATION 7-1-4 (3 dB DROOP)

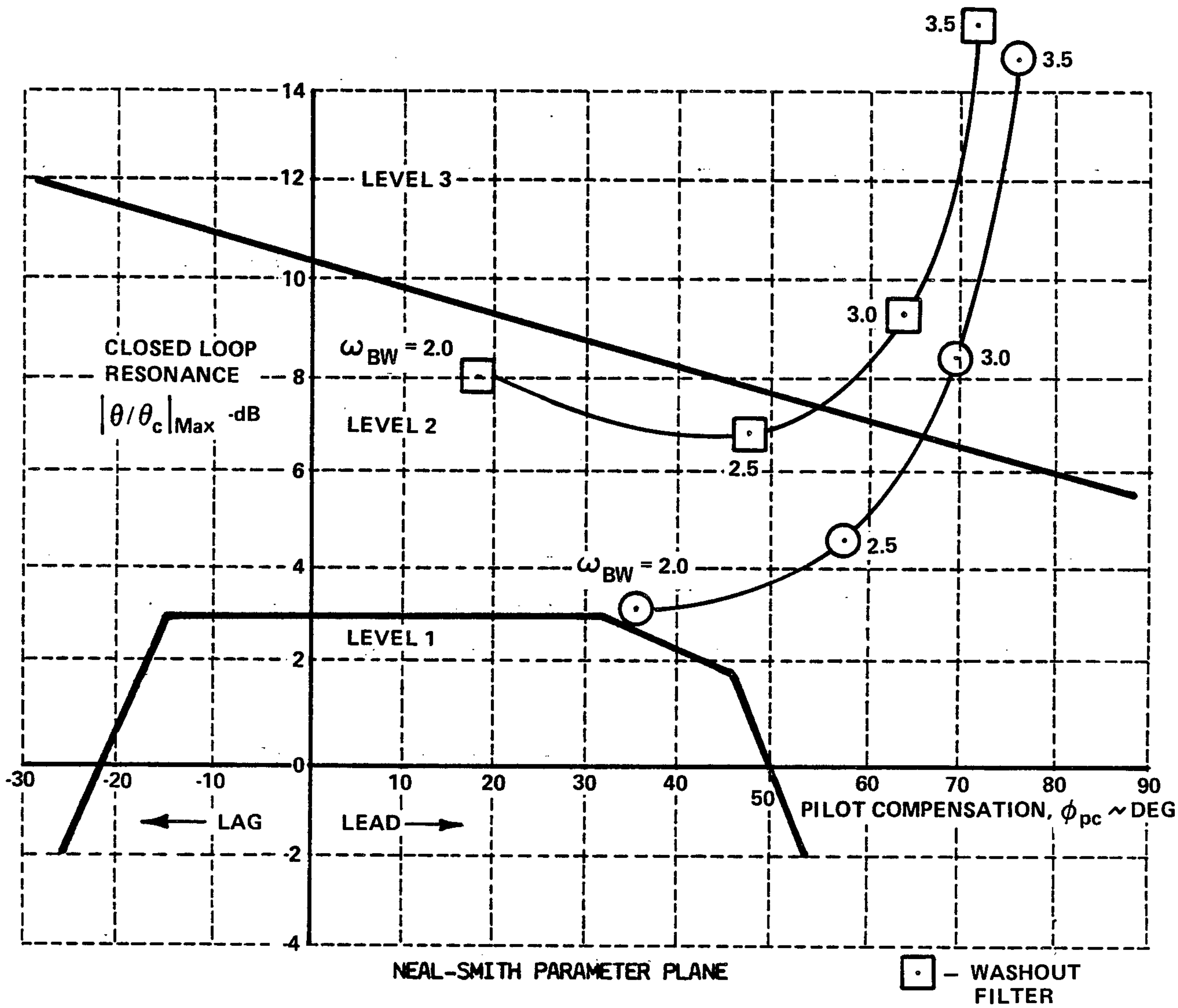


Figure 39 CONFIGURATION 8-1-5 (3 dB DROOP)

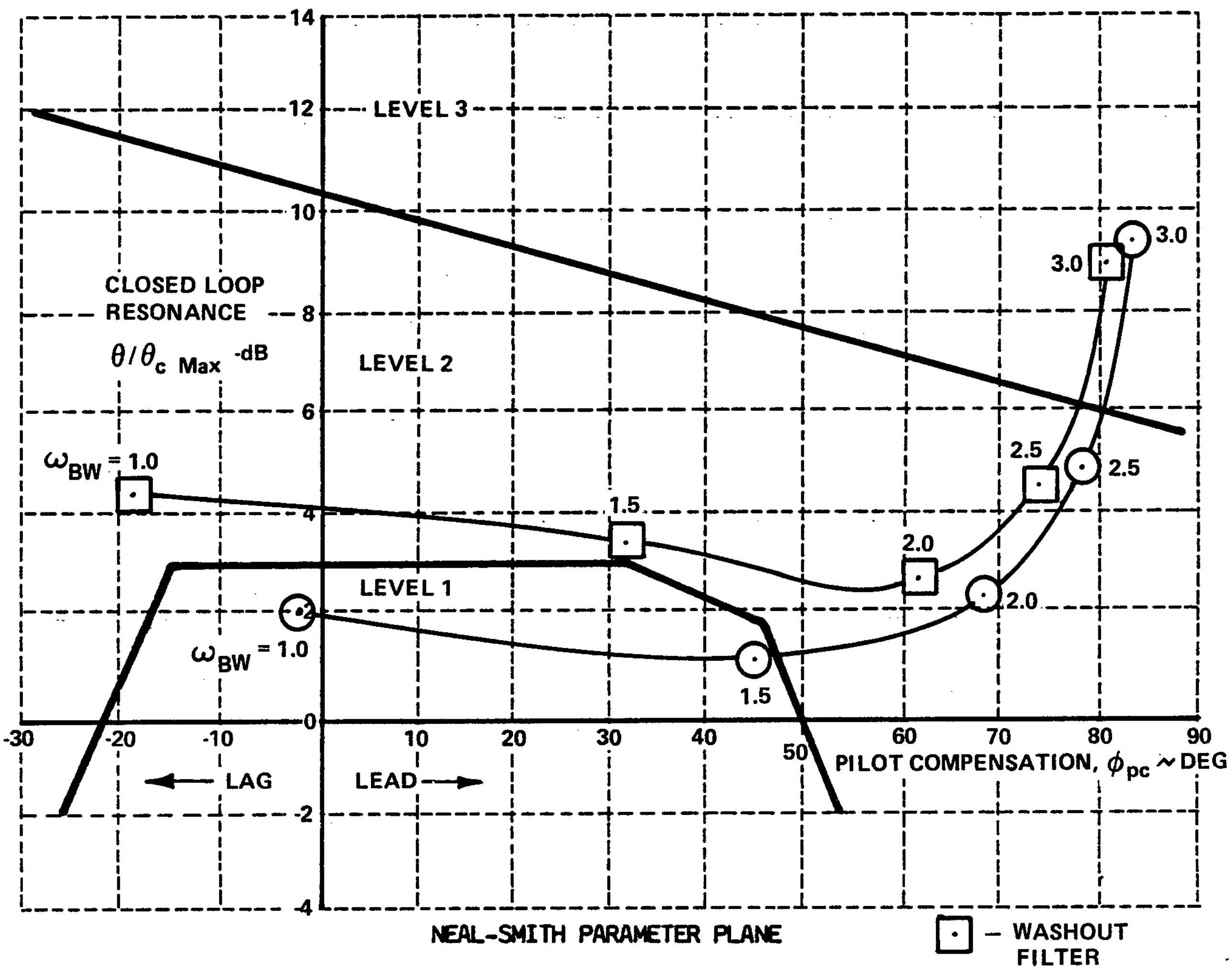


Figure 40 CONFIGURATION 8-2-5 (3 dB DROOP)

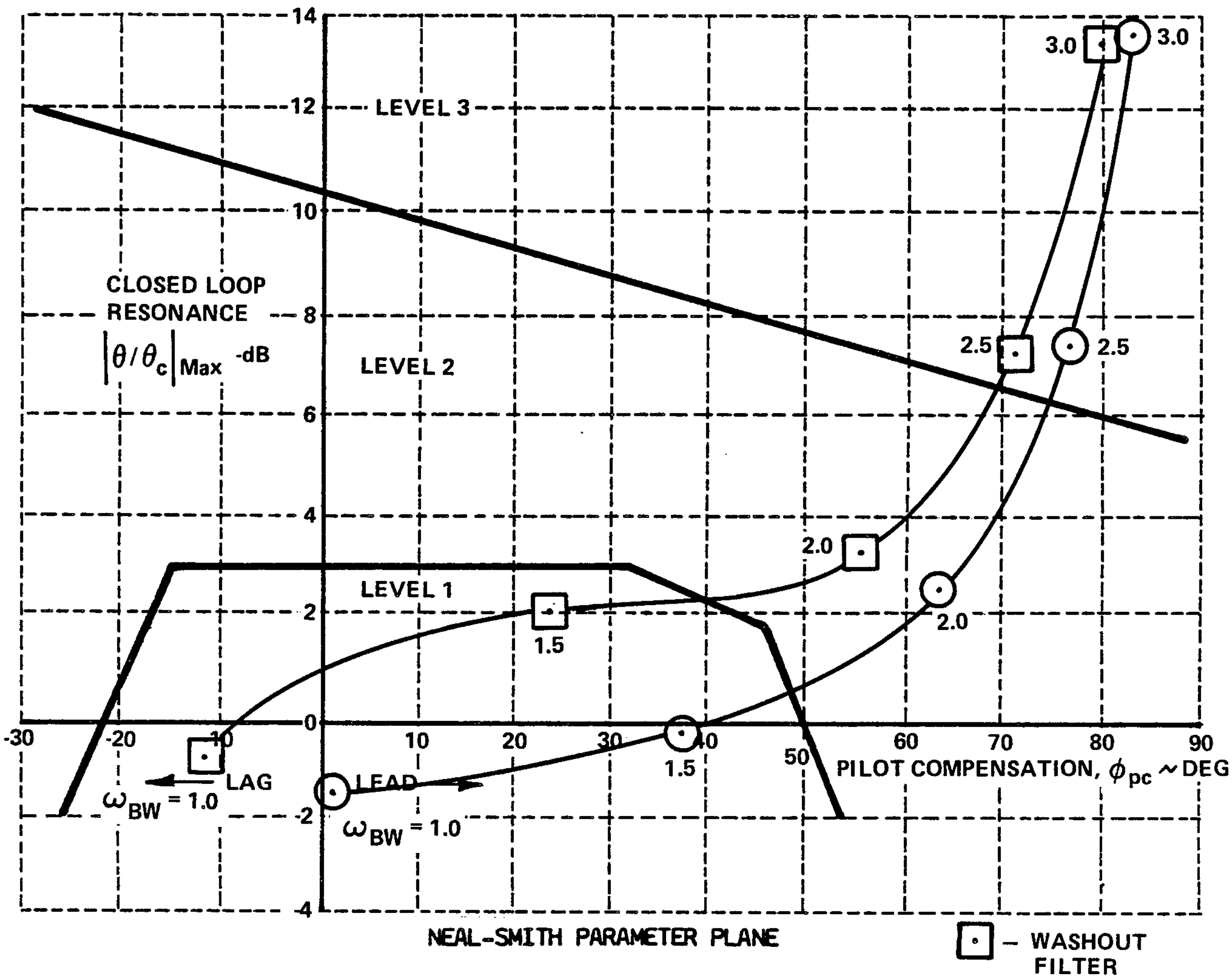
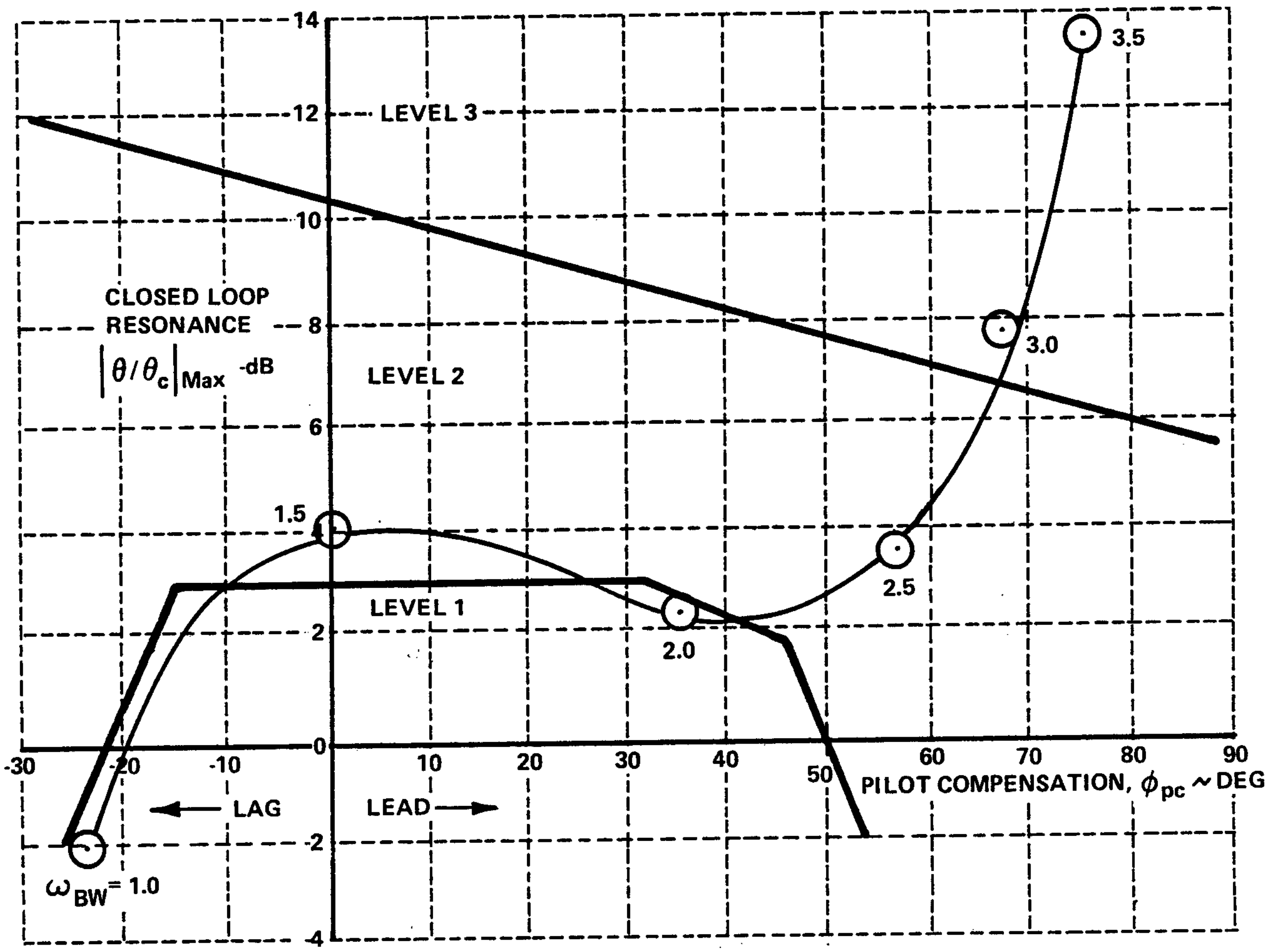


Figure 41 CONFIGURATION 8-3-5 (3 dB DROOP)



NEAL-SMITH PARAMETER PLANE

Figure 42 CONFIGURATION 8-4-6 (3 dB DROOP)

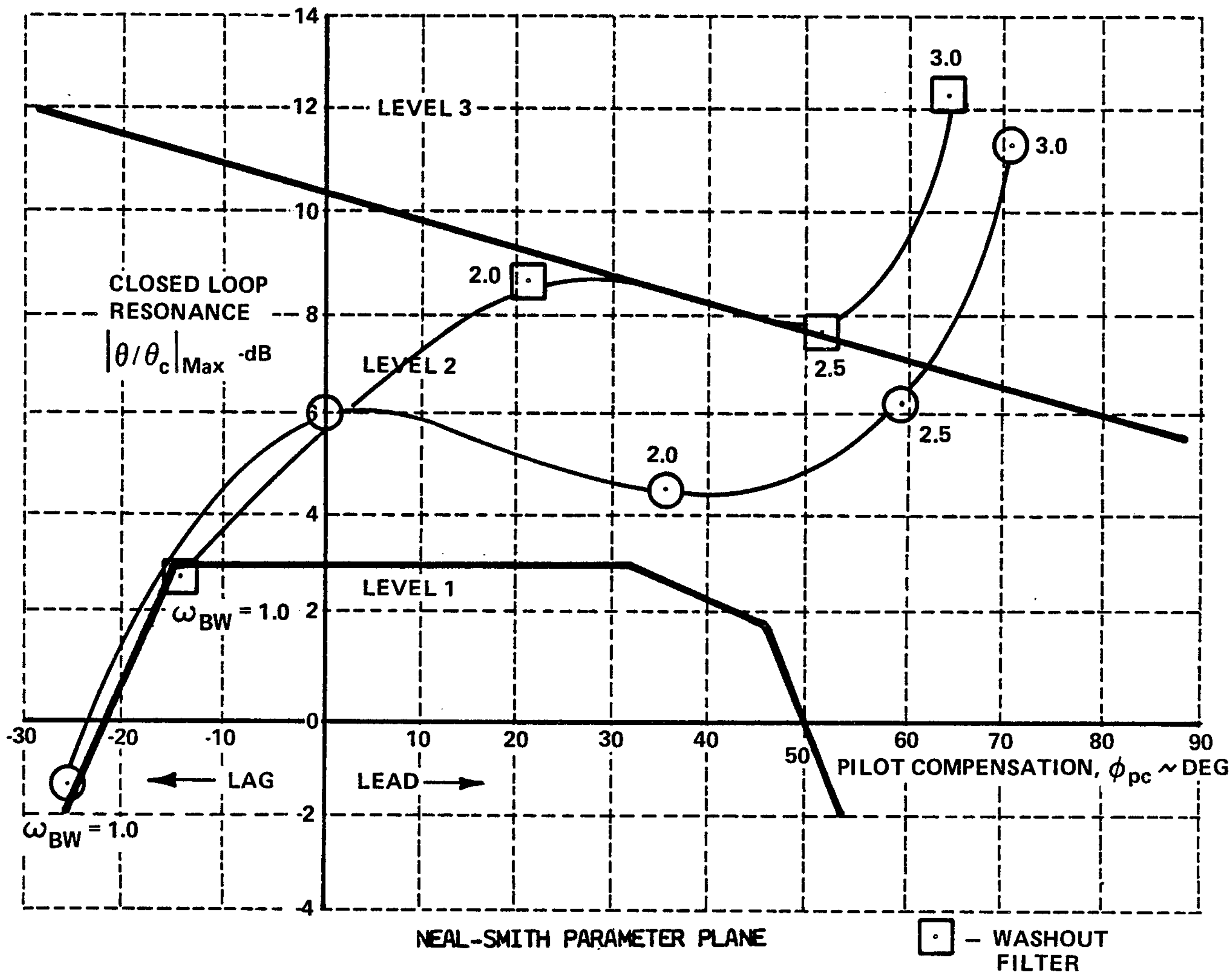


Figure 43 CONFIGURATION 8-5-5 (3 dB DROOP)

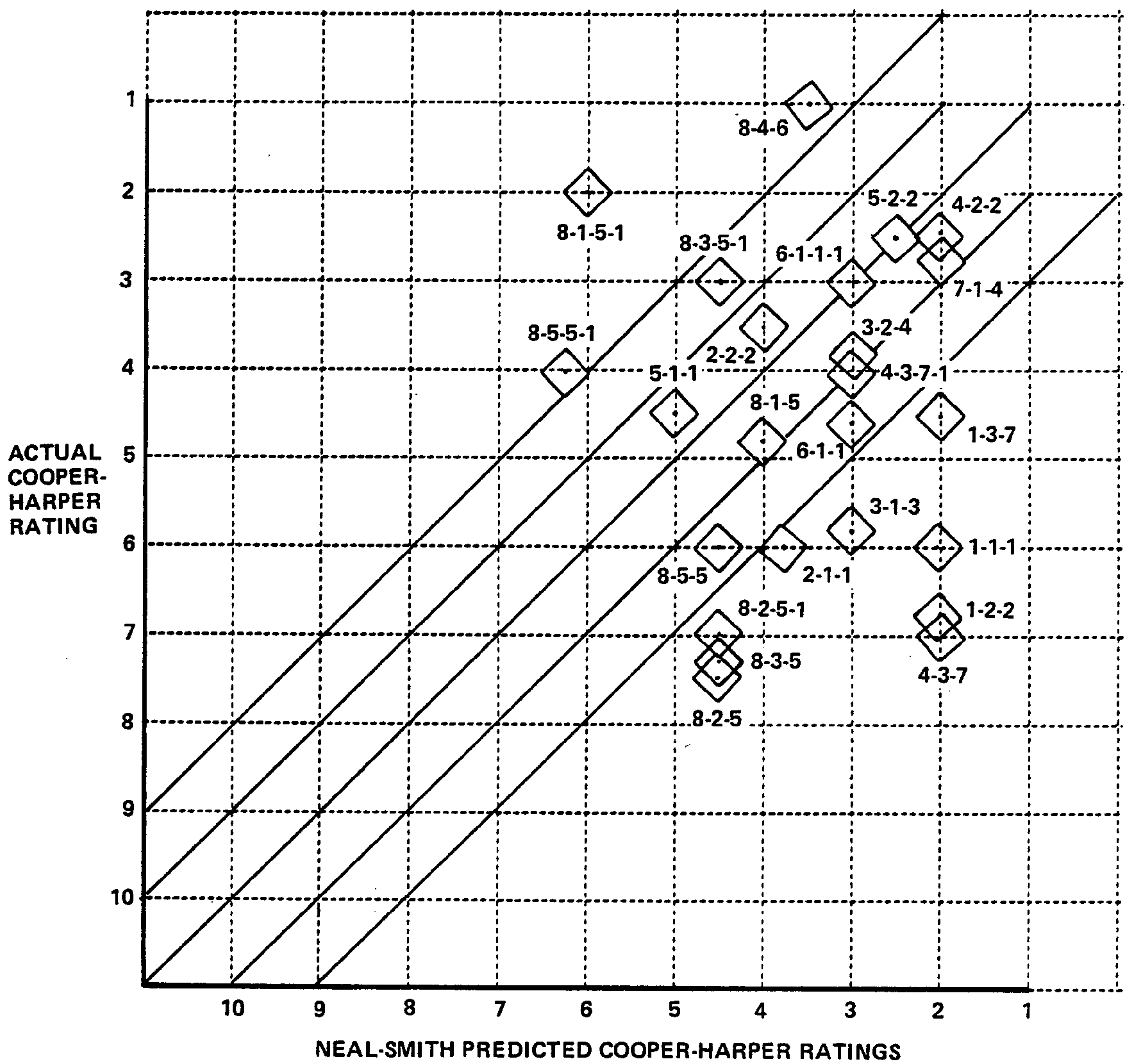


Figure 44 COMPARISON OF ACTUAL PILOT RATINGS AND NEAL-SMITH PREDICTED PILOT RATINGS (ω_{BW} = 2.0)

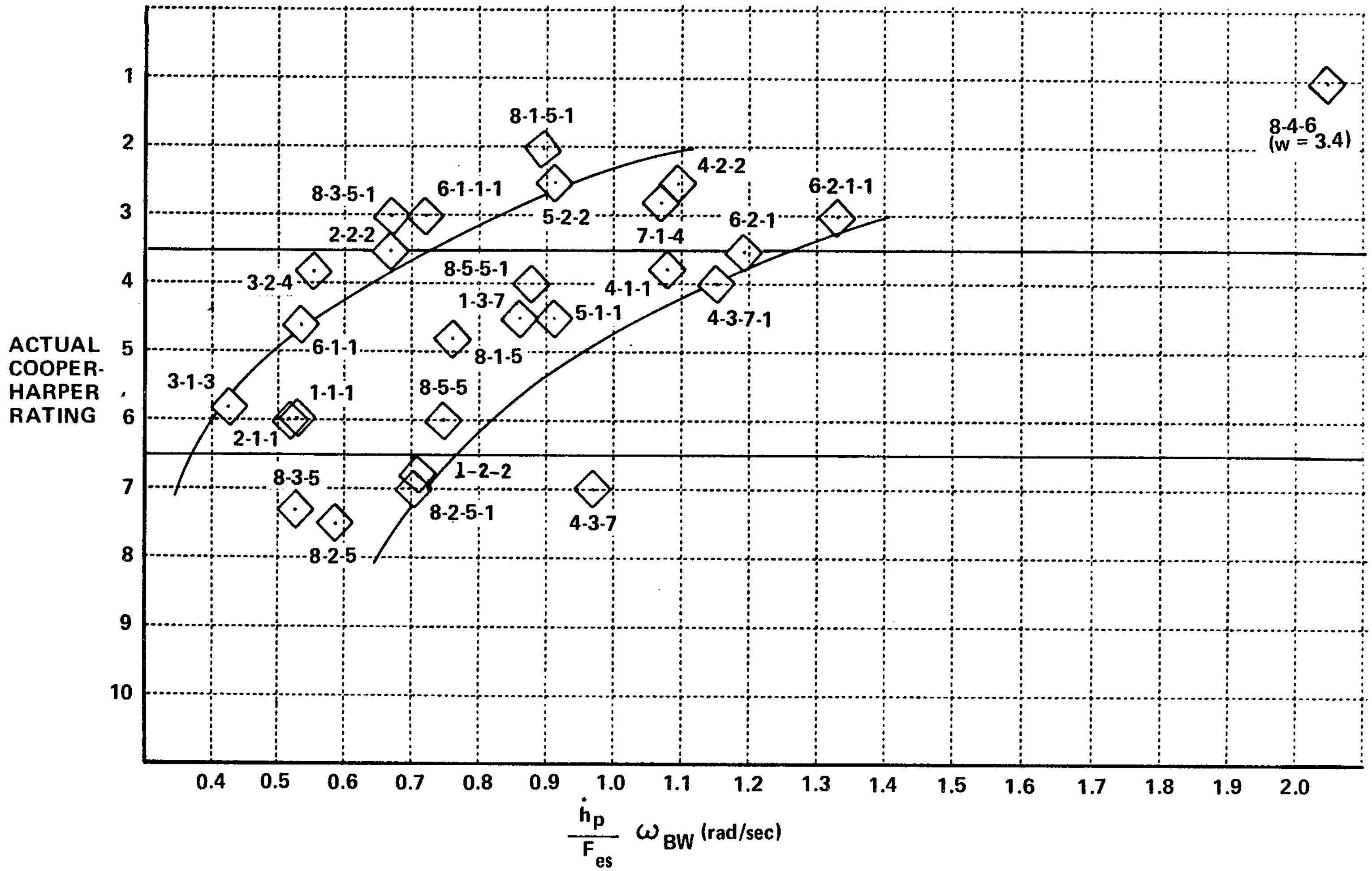


Figure 45 COMPARISON OF $\dot{h}_p/F_{es}$ BANDWIDTH AND ACTUAL PILOT RATINGS

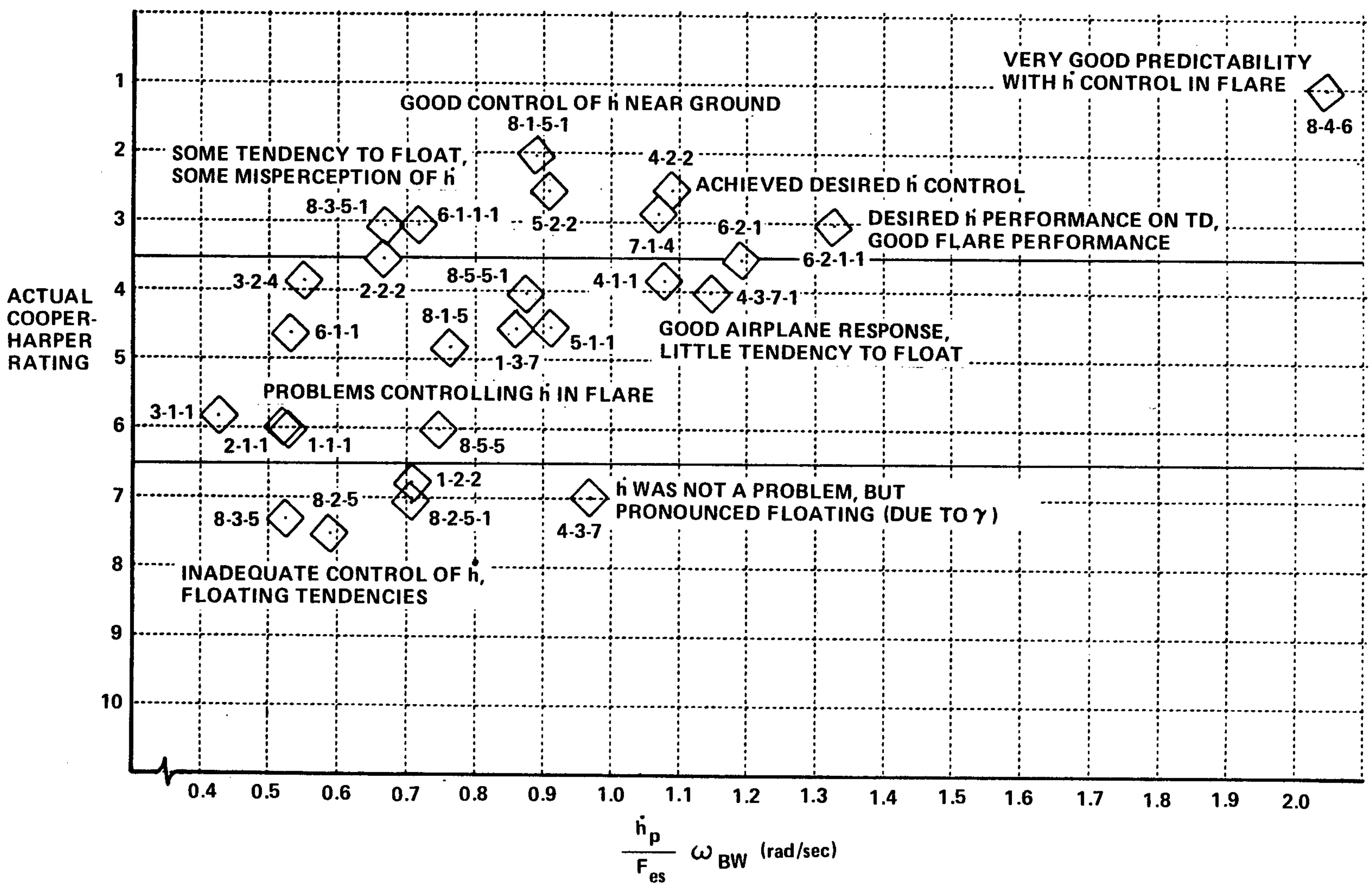


Figure 46 PILOT COMMENTS REGARDING ALTITUDE RATE CONTROL

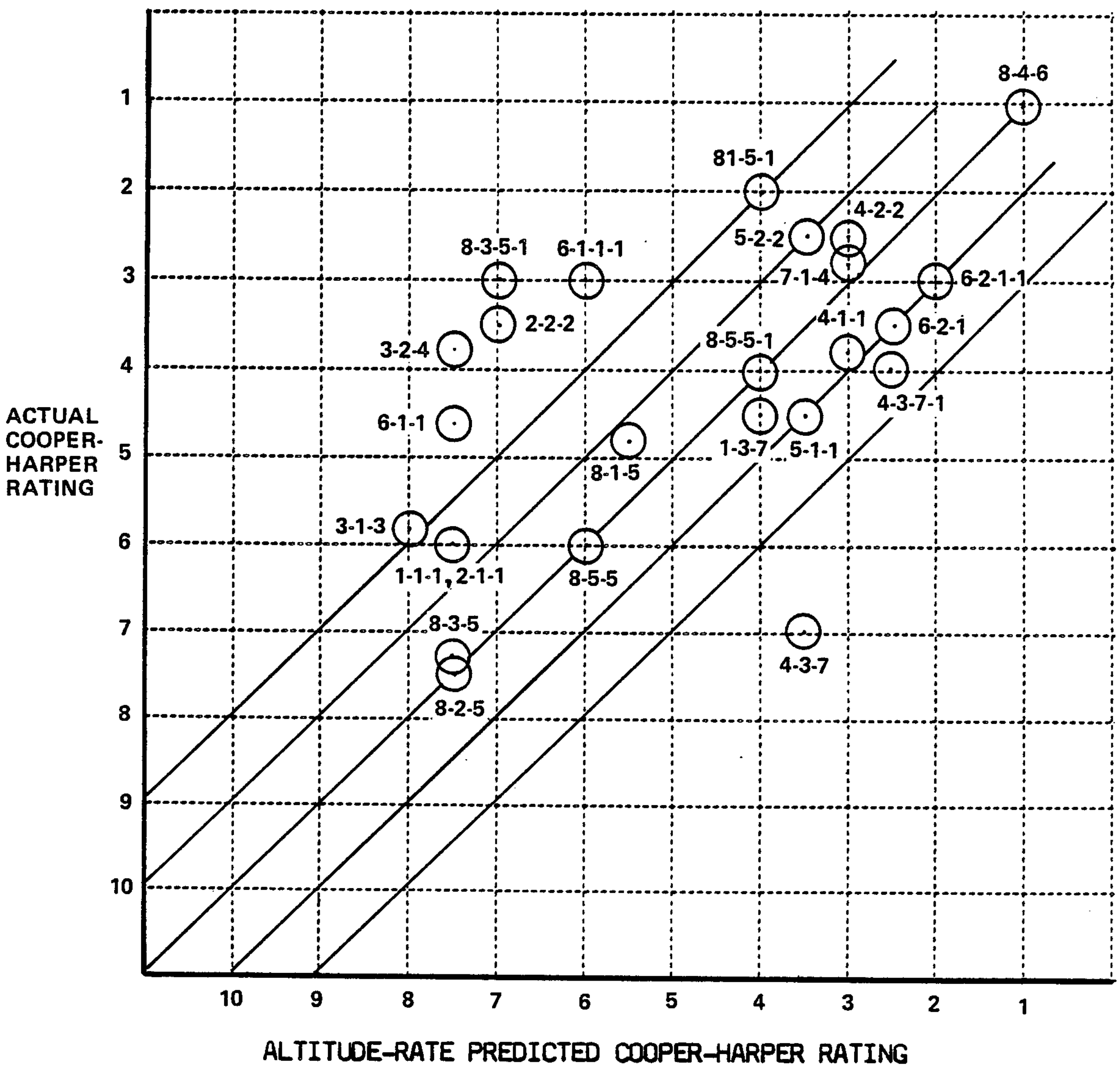


Figure 47 COMPARISON OF ACTUAL PILOT RATINGS AND ALTITUDE RATE PREDICTED PILOT RATINGS

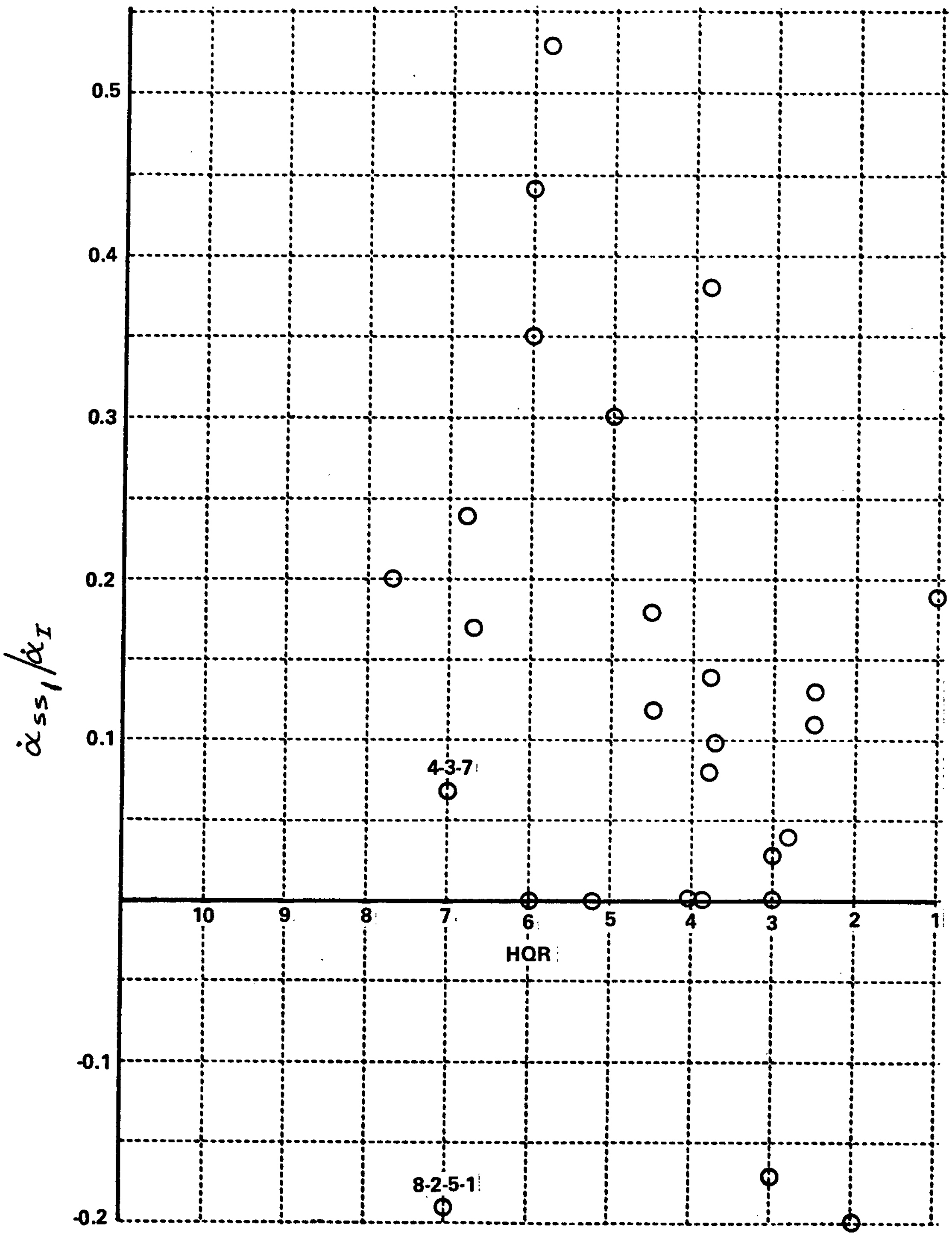


Figure 48 CORRELATION OF $\dot{\alpha}$ PARAMETER

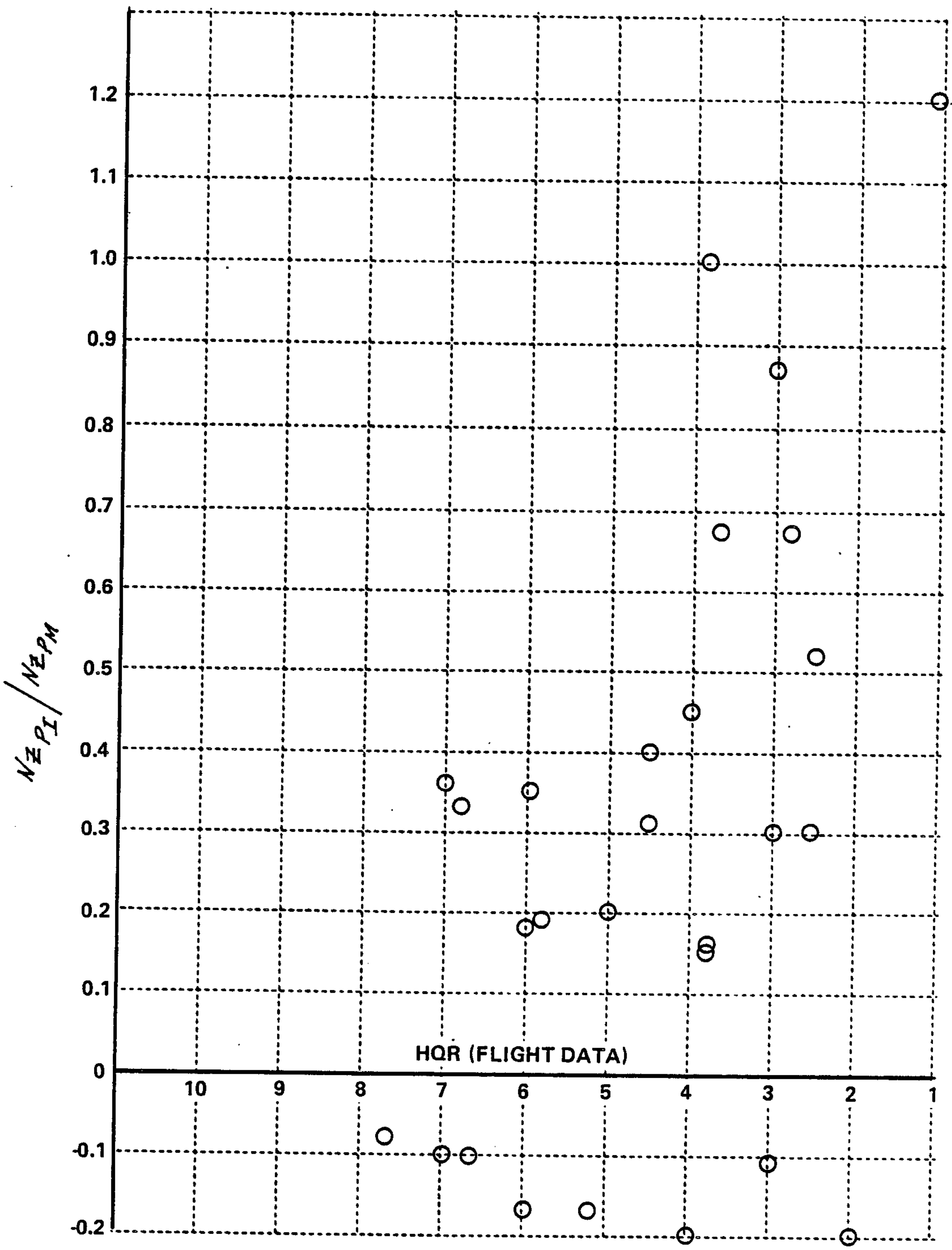
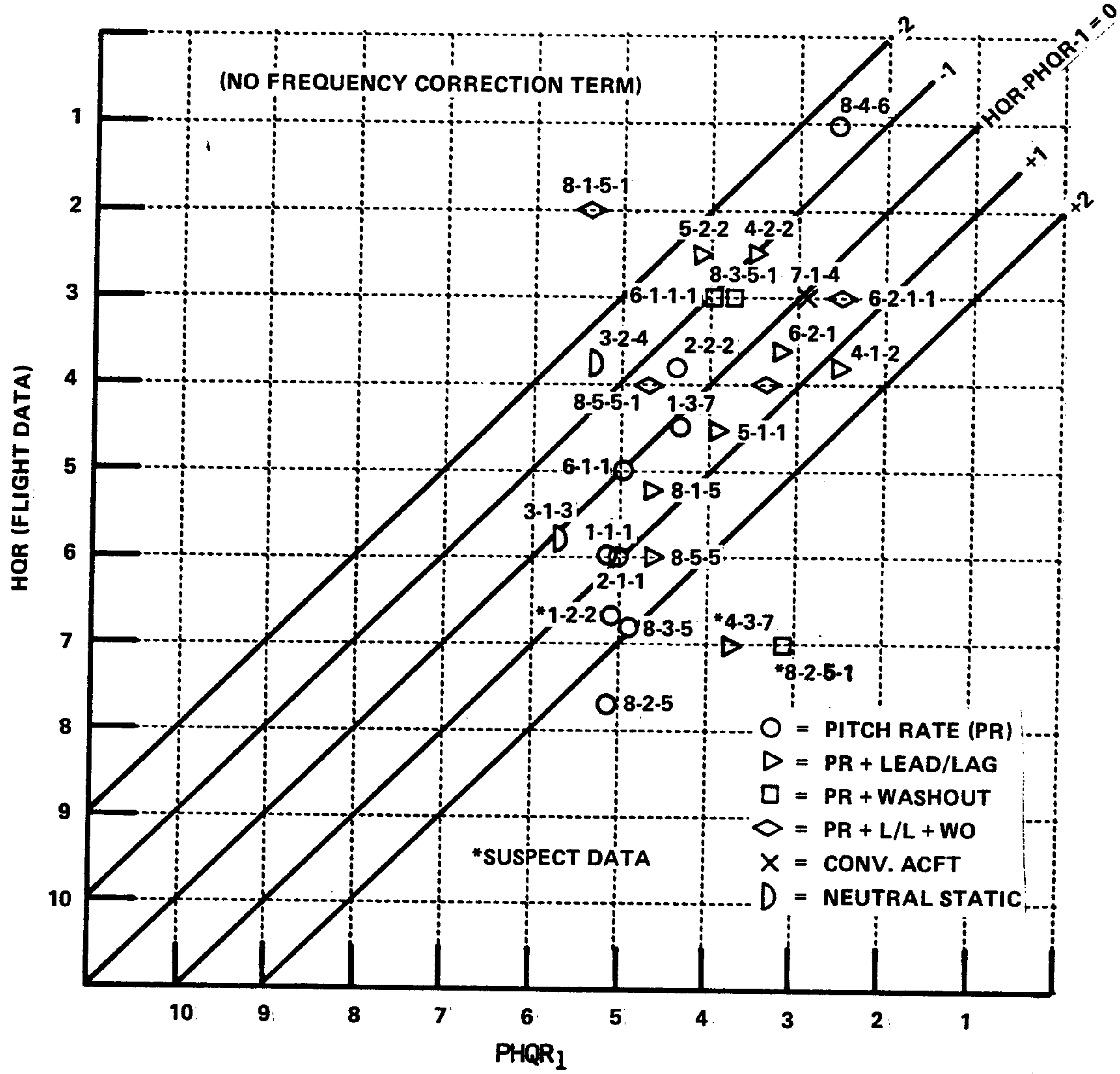


Figure 49 CORRELATION OF Nz_p PARAMETER

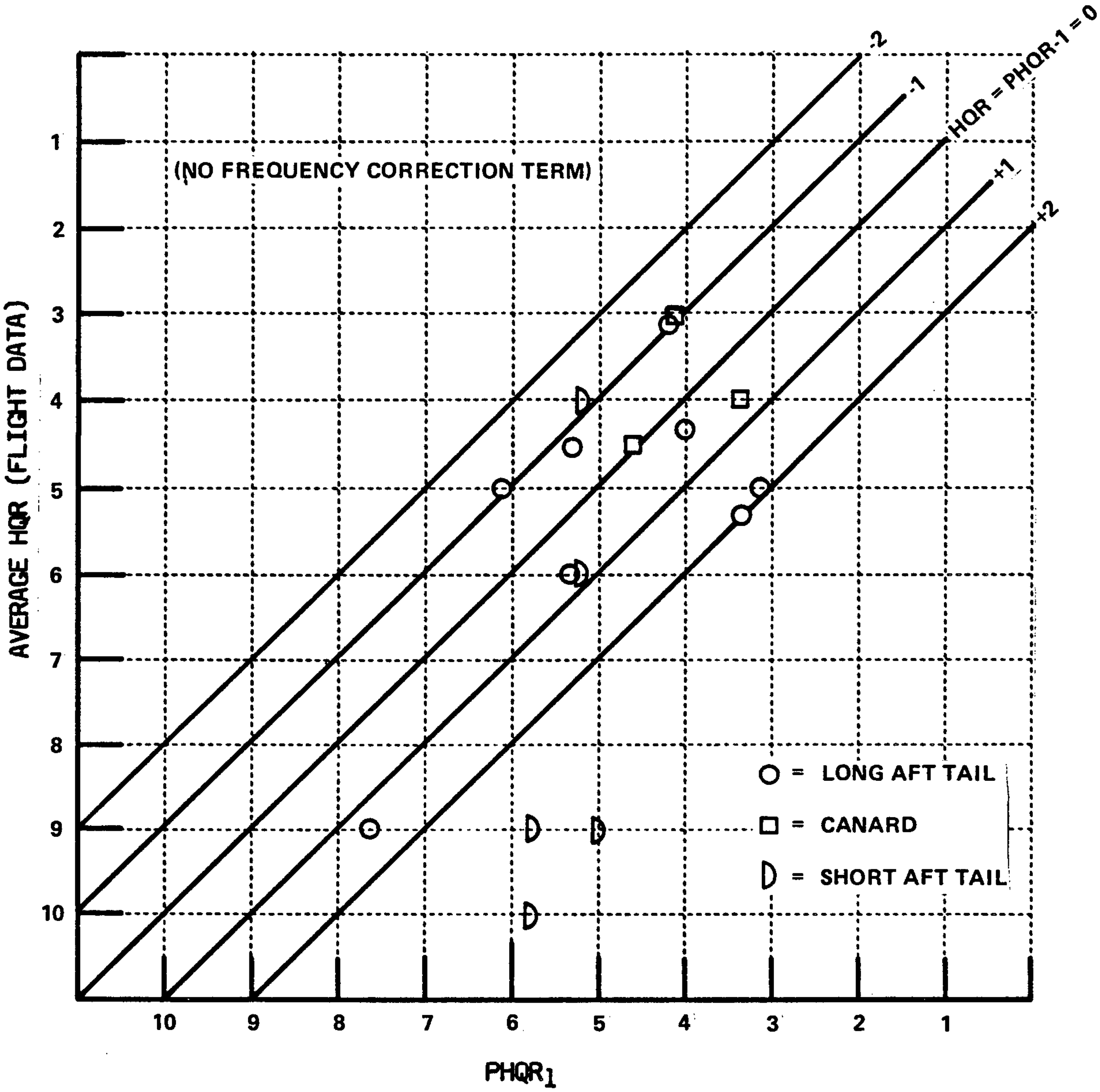


$$PHQR_1 = 3.6\,\dot{\alpha}' - 2.0\,N'_{z_p} + 4.3$$

WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\ ,\quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

Figure 50 PREDICTED HQR (PHQR) VS FLIGHT HQR (HQR) (FINAL APPROACH AND FLARED LANDING) PITCH RATE PROGRAM (1983)



$$PHQR_1 = 3.6\,\dot{\alpha} - 2.0\,N_{z_p} + 4.3$$

WHERE:

$$\dot{\alpha} = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\,, \quad N_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

Figure 51 PREDICTED HQR (PHQR) VS FLIGHT HQR (HQR) (INSTRUMENT APPROACH TO SIMULATED FLARED TOUCHDOWN) LARGE AIRCRAFT PROGRAM (1981)

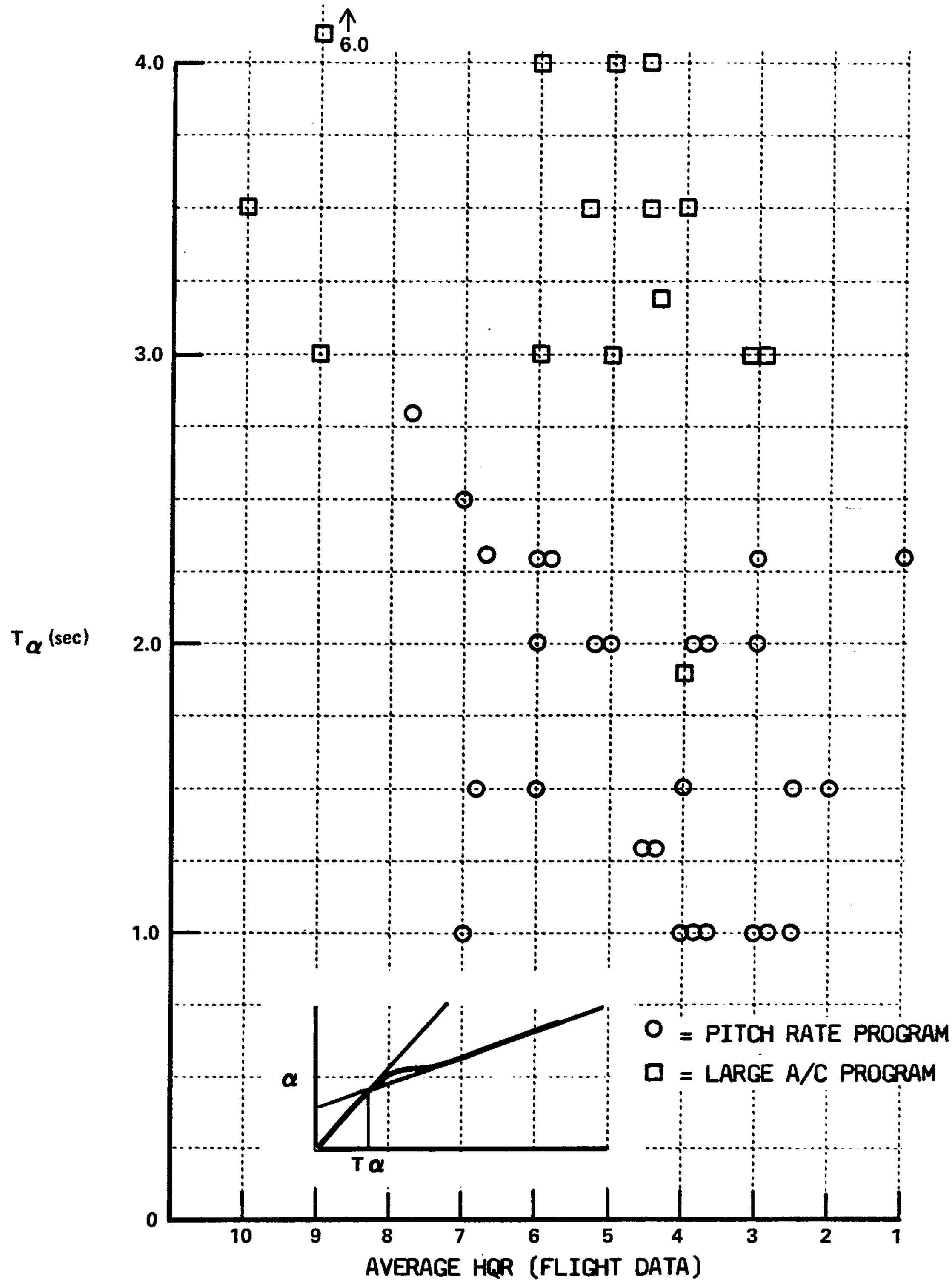
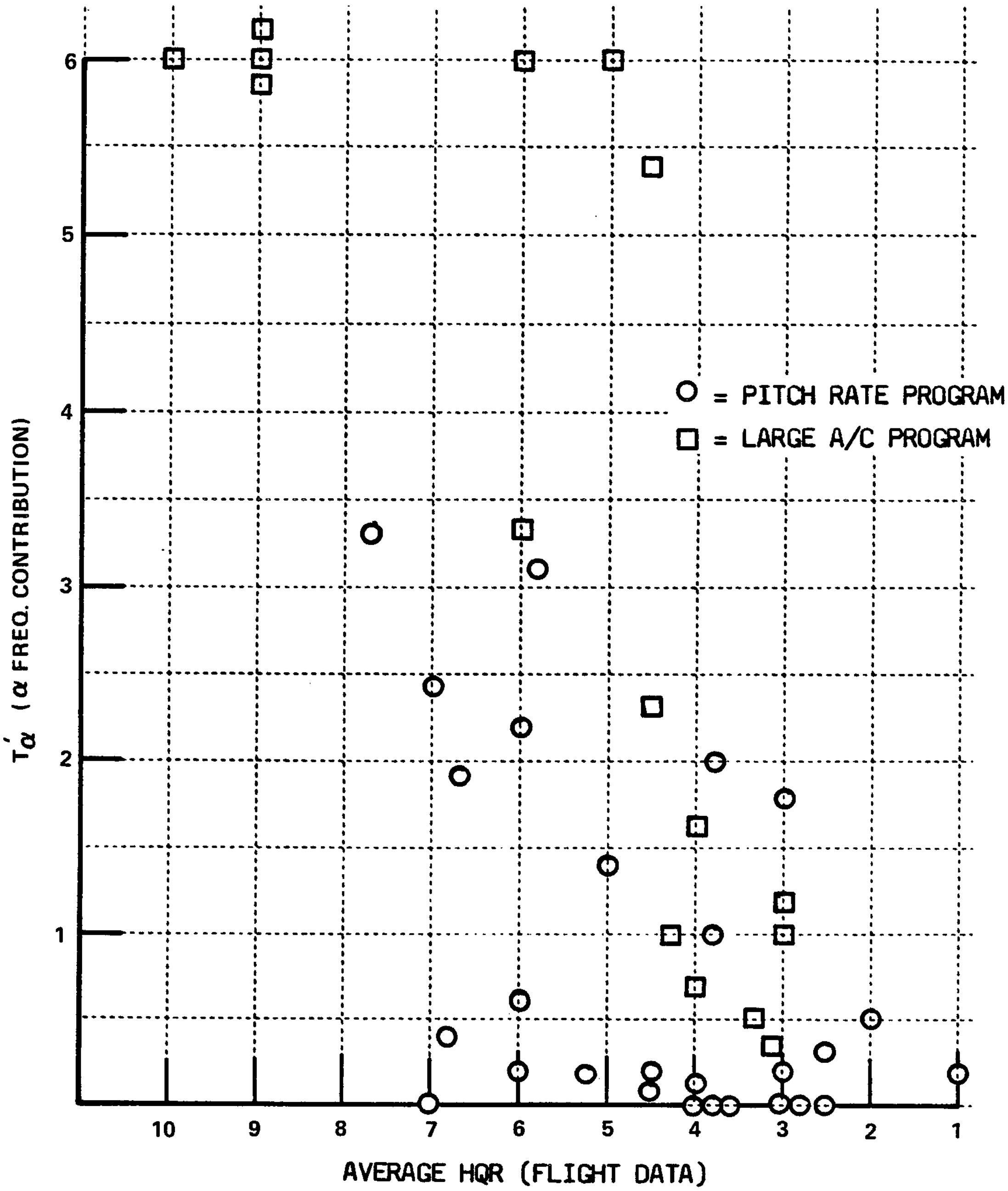


Figure 52 CORRELATION OF T_α PARAMETER (WHERE T_α = TIME TO INTERSECTION OF INITIAL AND STEADY STATE SLOPES OF α RESPONSE TO STEP)

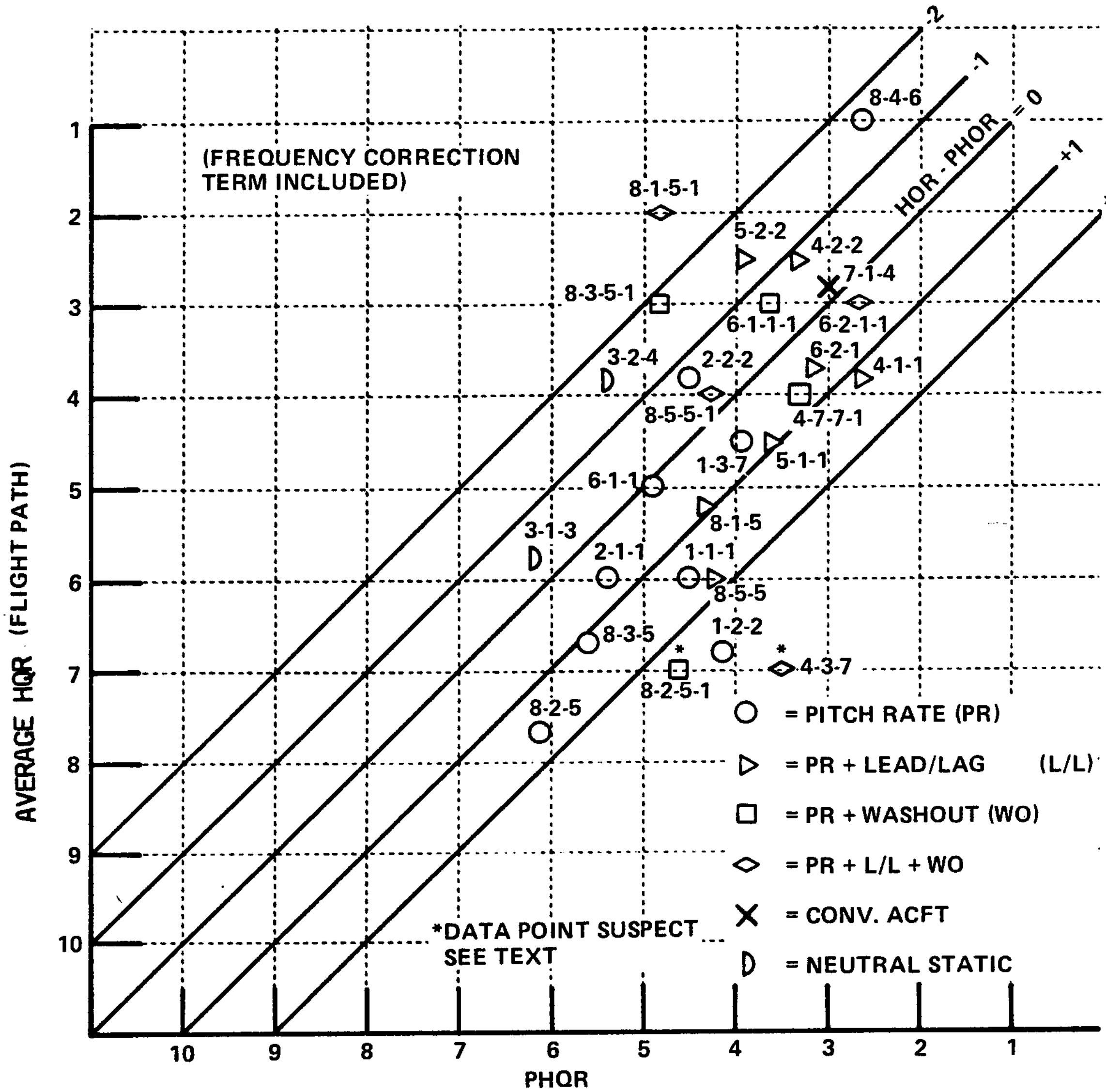


WHERE:

$$T'_\alpha = \left[|T\alpha - 1| \left(\frac{|\dot{\alpha}'| + 0.05}{|Nz'_p| + 0.05} \right) \right]$$

(FOR $T'_\alpha > 6$, LET $T'_\alpha = 6.0$)

Figure 53 CORRELATION OF WEIGHTED T_α TERM (T'_α)



$$PHQR = 1.7\,\dot{\alpha}' - 1.44\,N'_{z_p} + 0.55\,T'_{\alpha} + 3.9$$

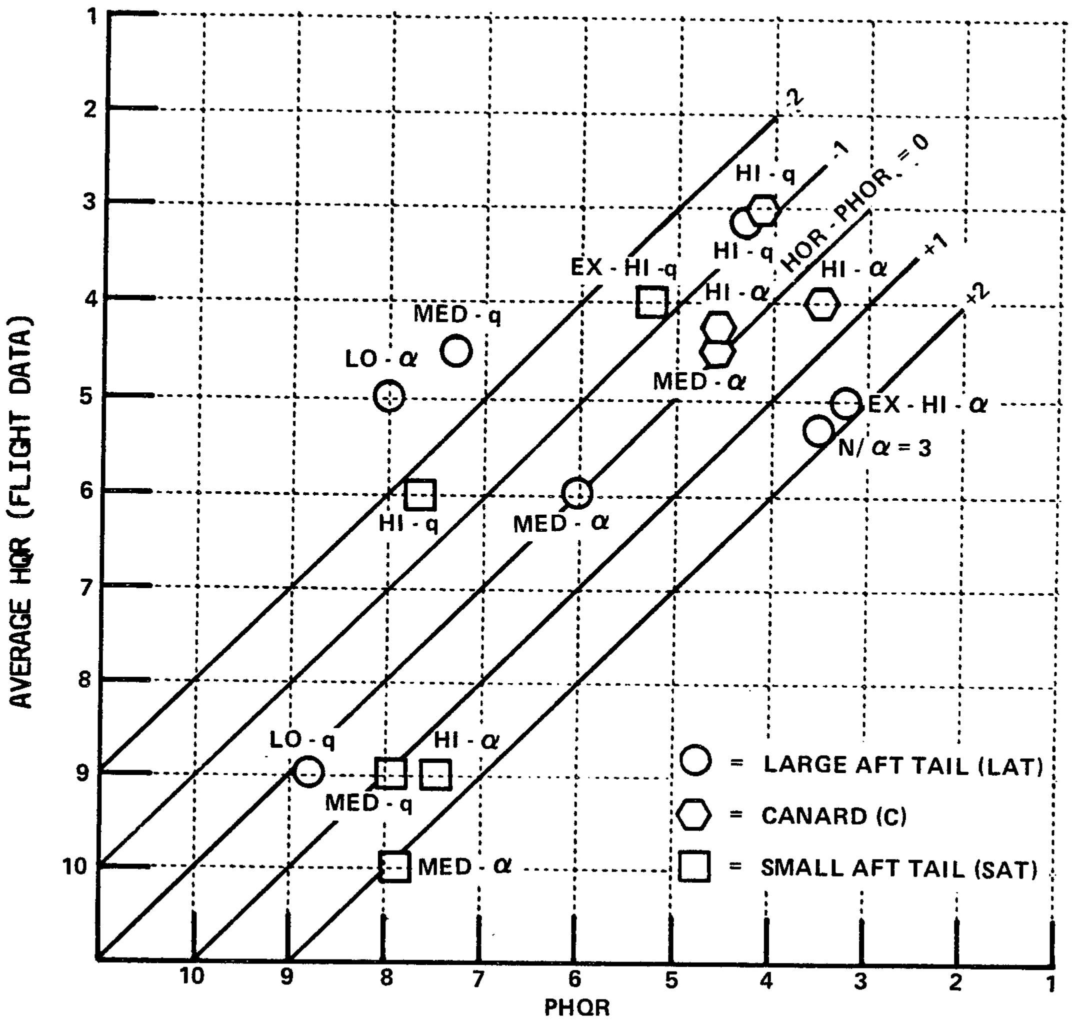
WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\,, \quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

$$T'_{\alpha} = |T_{\alpha} - 1| \left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05}\right]$$

(for $T'_{\alpha} > 6$, let $T'_{\alpha} = 6.0$)

Figure 54 PREDICTED HQR (PHQR) VS. FLIGHT HQR (HQR) FINAL APPROACH AND FLARED LANDING) PITCH RATE PROGRAM (1983)



$$PHQR = 1.7\ \dot{\alpha}' - 1.44\ N'_{z_p} + 0.55\ T'_{\alpha} + 3.9$$

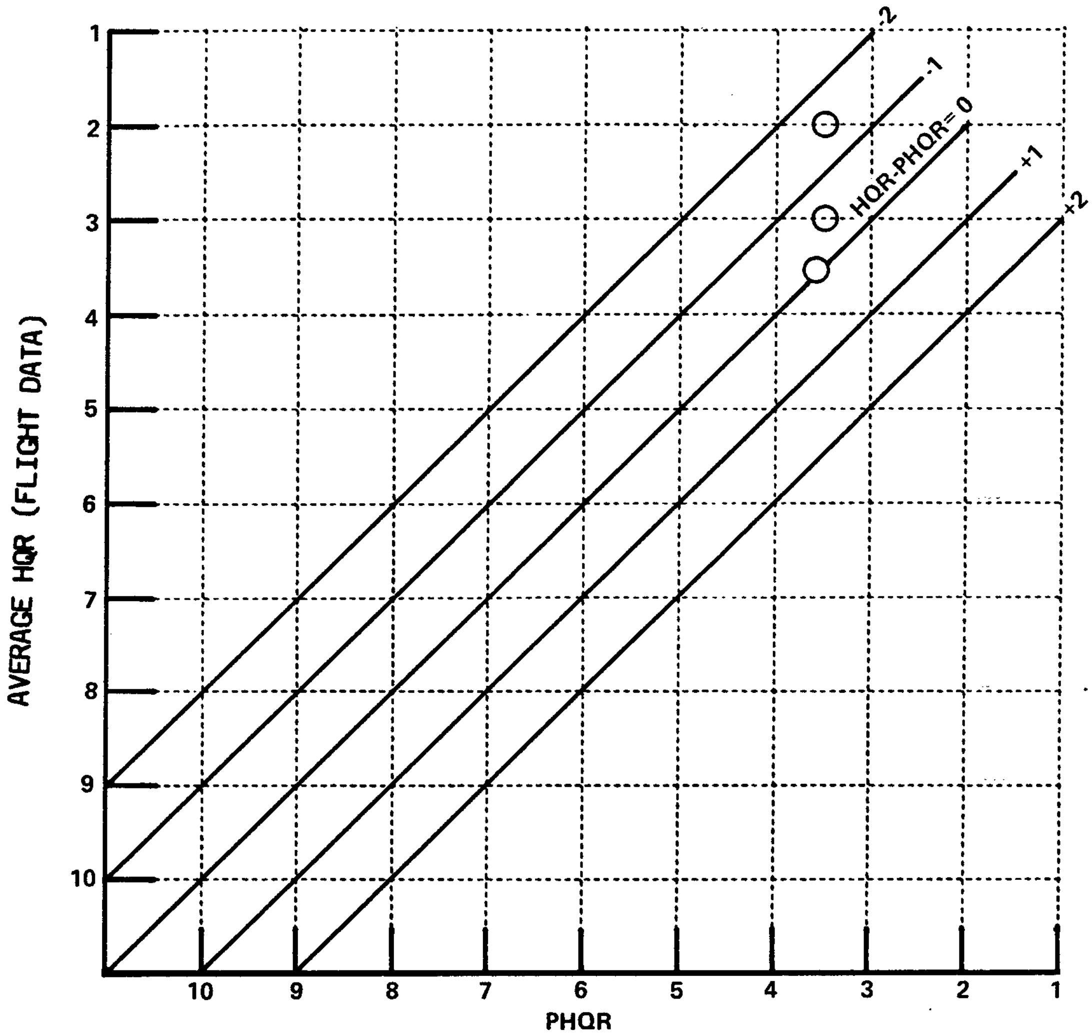
WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\ ,\quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

$$T'_{\alpha} = |T_{\alpha} - 1| \left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05}\right]$$

(for $T'_{\alpha} > 6$, let $T'_{\alpha} = 6.0$)

Figure 55 PREDICTED HQR (PHQR) VS. FLIGHT HQR (HQR) (FLARED LANDINGS, SIMULATED TOUCHDOWN) LARGE AIRCRAFT PROGRAM (1981)



$$PHQR = 1.7\,\dot{\alpha}' - 1.44\,N'_{z_p} + 0.55\,T'_{\alpha} + 3.9$$

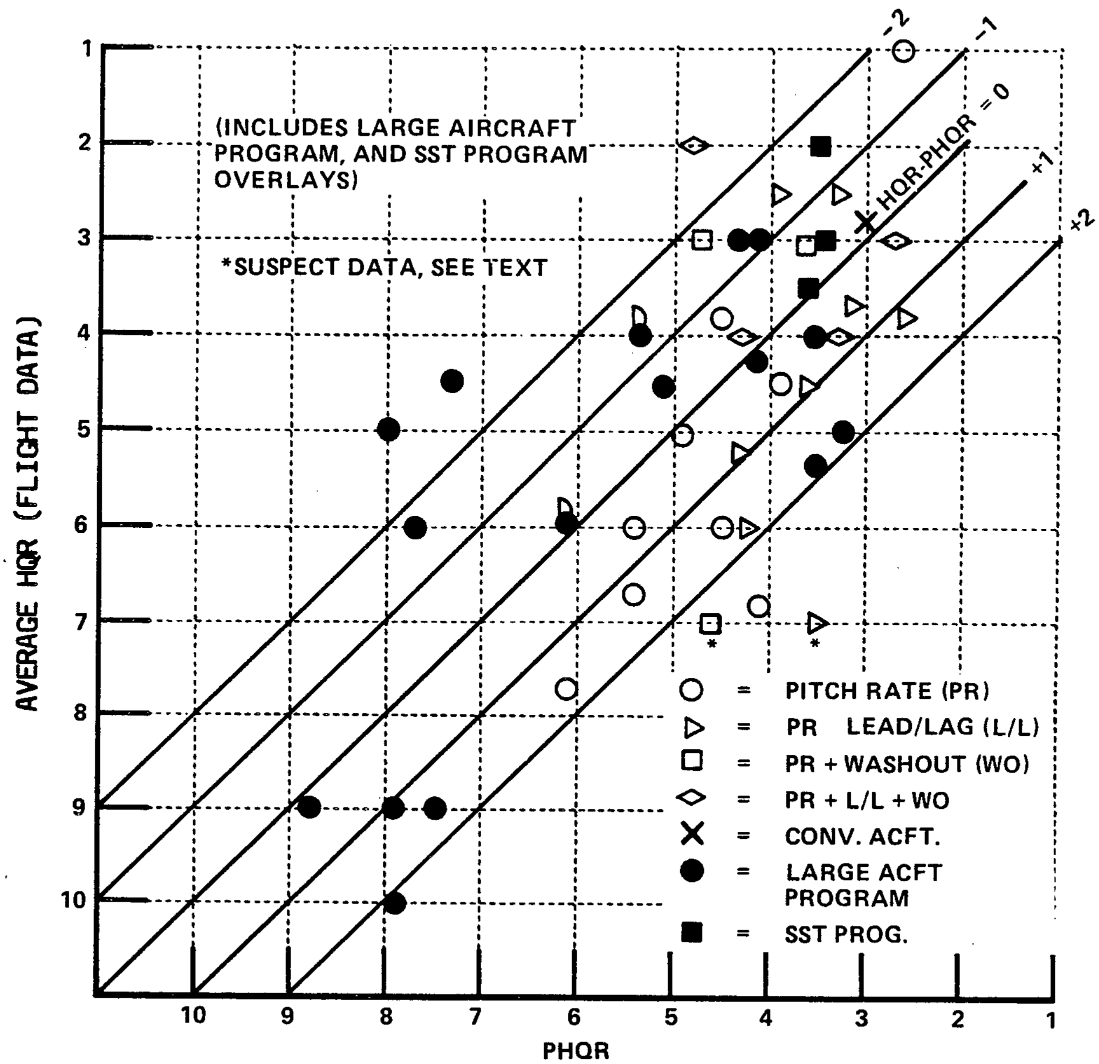
WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\,, \quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

$$T'_{\alpha} = |T_{\alpha} - 1| \left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05}\right]$$

(for $T'_{\alpha} > 6$, let $T'_{\alpha} = 6.0$)

Figure 56 PREDICTED HQR (PHQR) VS. FLIGHT HQR (HQR)$^{-2}$ (FINAL APPROACH AND FLARED LANDING) SST PROGRAM DATA (1972)



$$PHQR = 1.7\,\dot{\alpha}' - 1.44\,N'_{z_p} + 0.55\,T'_{\alpha} + 3.9$$

WHERE:

$$\dot{\alpha}' = \dot{\alpha}_{ss_1}/\dot{\alpha}_I\ ,\quad N'_{z_p} = N_{z_{p_I}}/N_{z_{p_{max}}}$$

$$T'_{\alpha} = |T_{\alpha} - 1| \left[\frac{|\dot{\alpha}'| + 0.05}{|N'_{z_p}| + 0.05}\right]$$

$$(\text{for } T'_{\alpha} > 6\ ,\ \text{let } T'_{\alpha} = 6.0)$$

Figure 57 PREDICTED HQR (PHQR) VS. FLIGHT HQR (HQR) (FINAL APPROACH AND FLARED LANDING) PITCH RATE PROGRAM